JOURNAL OF ANIMAL BEHAVIOR

VOL. 1. SEPTEMBER-OCTOBER, 1911. No. 5.

HABIT FORMATION IN FROGS

ASA A. SCHAEFFER

University of Tennessee

One figure

While investigating feeding reactions in frogs, especially with regard to the basis upon which discrimination is made, I incidentally made some observations bearing upon habit formation in these animals that contribute to a better understanding of their mental powers. It has seemed to me most satisfactory to incorporate these results in a separate paper instead of making them a part of an investigation on general feeding reactions in frogs, inasmuch as my results on habit formation differ somewhat from those obtained by Yerkes and others. As we shall see later, the difference is due to the fact that the feeding instinct seems to be more amenable to rapid habit formation than the instinct upon which Yerkes based his experiments.

The work was carried on at two different places. The first set of observations was made at Cold Spring Harbor, Long Island, and the second set at Knoxville, Tennessee. Four frogs were experimented on at Cold Spring Harbor. 1. An adult female *Rana sylvatica* Le Conte. 2. A *Rana virescens* Kalm, of uncertain sex, about three-quarters grown. 3. A female *Rana clamata* Daudin, about three-quarters grown, designated in the observations as "medium." 4. A male *Rana clamata*, about one-quarter grown, designated as "small." The *R. sylvatica* was caught at Gilbert, Pennsylvania; the other three were caught at Cold Spring Harbor.

All these frogs were kept in a single cage about 30 by 30 by 40 cm., made of galvanized sheet-iron and fly screening. Into the cage was placed a berry dish about 25 cm. in diameter, in which were placed some pebbles, a large stone, and about a liter of water. A small strip of board was laid on the dish for the frogs to sit on. In other parts of the cage were placed dead leaves, grass and twigs. The cage was made as "homelike" as possible. The frogs had ample opportunity to hide either in the water or in the grass. Opportunity to hide is an ever present feature in a wild frog's environment, and hiding places should not be neglected when frogs are caged. The cage was placed to the side of a south window which allowed a small amount of sunlight each day.

The frogs were kept under almost constant observation, as far as their feeding is concerned, for four weeks before any of the data in this paper were recorded. So much time was, however, not necessary for the frogs to accommodate themselves to their unusual surroundings. All but *R. virescens* ate in a normal manner in about four days after being placed in the cage; *R. virescens* was a shy frog and did not behave normally as far as its feeding reactions are concerned until about two weeks had passed.

The food of the frogs up to the time of the observations on habit forming consisted of all manner of insects: house flies; hornets; wasps, adults and larvae; ants; locusts, nymphs and adults; beetles; bees; cabbage butterflies (*Pieris rapae*), adults and larvae; bugs; leaf hoppers; and also earthworms, centipedes, snails and sowbugs. Feeding was done at irregular intervals, sometimes twice a day and sometimes once in two days. A sweep net was used to collect most of the food. No new food was placed into the cage as long as living moving food was still there. The frogs seemed to be in very good condition throughout the whole series of experiments.

The first series of observations were yielded by what might appropriately be termed the natural history method of experimentation, since the reactions of the frogs were exactly such as might be called forth any day of their lives in their normal environment. The irregularity of the food supply may be considered normal, for the quantity of available food in natural conditions must be very variable and irregular, depending as it does on temperature, humidity, light, etc. On the whole, we may say that the frogs were subjected to no conditions that might not befall them under normal circumstances.

Inasmuch as it was possible that the food placed into the cage engaged the attention of all the four frogs simultaneously, the observations will be presented in exactly the order in which they were made and recorded.

OBSERVATIONS

July 26.—Two hairy caterpillars about 2 cm. long (of undetermined species) were placed into the cage with the frogs They were eaten, but unfortunately my notes do not state which frogs ate them. The omission does not materially affect the conclusion to be drawn later.

July 29.—I placed 30 of the hairy caterpillars into the cage. The caterpillars crawled over everything in the cage. The following is an account of the behavior of each frog toward the caterpillars. The observations lasted about two hours.

Rana sylvatica attempted to eat a caterpillar seven different times within an hour, but rejected it each time. Following these trials no other caterpillars were visibly reacted to. By attempting to eat a caterpillar and then rejecting it, is meant this: The frog shot out the tongue in the normal manner, bringing the caterpillar back to the mouth, then extruding the tongue slowly, slightly wriggling it. In most cases this muscular wriggling freed the caterpillar from the tongue; if it did not, the withdrawal of the tongue into the mouth scraped off the caterpillar in nearly every case. Sometimes the tongue was wriggled without a previous withdrawal into the frog's mouth.

Rana clamata (medium) made only two trials of the caterpillars, rejecting both, and then ceased to react toward them for a while. The frog then jumped into the dish of water. Subsequently a caterpillar crawled along the rim of the dish opposite the frog. The frog walked over to within 3 cm. of the caterpillar, and paid close attention to its movements for about 15 seconds. Then the frog walked backwards about 8 cm. resuming the original somewhat indifferent attitude. No further reactions toward the caterpillars were observed, although they crawled in most tempting situations.

Rana virescens made three trials of the caterpillars, rejecting every one. No other response to the caterpillars was observed.

July 30, 11 A. M.—I colored six caterpillars by sprinkling carmine powder on them, and six others by sprinkling with methylene blue powder. These colored caterpillars were then placed into the frog cage where they crawled around in normal fashion. Although they crawled in the most tempting positions for over an hour, not any of the frogs manifested any visible response. The very marked difference in coloring of these caterpillars was insufficient apparently to cause a break in the rapidly formed habit of avoiding hairy caterpillars. The color of the caterpillars evidently had little or nothing to do in the formation of the habit in this case.

July 30, 4 P. M.—The caterpillars when disturbed spin a thread of silk and suspend themselves on it until the disturbance is over, when they crawl back again to their original position. A normal caterpillar was observed to suspend itself in this manner about 5 cm. in front of the wood frog and about 3 cm. from the bottom of the cage. The caterpillar wriggled, and was snapped by the frog almost immediately. The caterpillar was held in the mouth for a half-second. The tongue was then thrown out and held out for two or three seconds. The caterpillar, however, stuck fast, and when the tongue was withdrawn into the mouth the caterpillar went with it. It was soon swallowed with seeming difficulty. The wood frog did not later react toward any of the crawling caterpillars.

The eating of this caterpillar does not indicate a dissolution of the recently formed habit of refusing this kind of organism. The stimuli from a wriggling suspended caterpillar are quite different from those of a crawling caterpillar. The stimuli from the crawling caterpillar were probably the only ones upon which the avoiding habit was based. (We have noted that color played little or no part in this case.) When these stimuli were absent, the previously formed habit of course could not operate.

Rana virescens. The caterpillars collect on the ceiling of the cage and then remain quiet if left to themselves for a few hours. It thus happened that the frog had not seen any crawling caterpillars for four and a half hours. When I placed a caterpillar on the rim of the berry dish in which the frog was sitting, the caterpillar was snapped up at once, but the tongue was quickly thrown out, and the frog being in the water, the caterpillar was washed off. This frog could not be induced to react toward another caterpillar. The three trials on the previous day had evidently not been quite sufficient to establish a habit lasting longer than one day.

Rana clamata (small) snapped up a caterpillar after it had dropped from the ceiling, and swallowed it with great difficulty. No visible attempt was made to reject it.

July 31.—I placed an adult locust (*Dissosteira carolina*) into the cage. *Rana clamata* (small) became interested after the locust had been in the cage a few minutes. When the locust had climbed up the side of the cage about 22 cm. above the floor, the frog jumped, but struck the side of the cage 3 cm. below the locust.

Rana clamata (medium) also became interested a few minutes after the small spring frog had jumped at the locust. The locust was climbing up the side of the cage, and when about 12 cm. above (vertically) and 7 cm. away (horizontally) the frog jumped, landing against the side of the cage below the locust. A few minutes later I induced the locust to climb up the side of the cage at another point. When it was about 10 cm. above the frog, the frog straightened up, and after examining the locust for about 30 seconds, moved back a little and squatted down. The locust was all the time slowly climbing, and always within reach of the frog.

It would have been impossible for the small *R. clamata* to eat the locust, and it would have been very difficult for *R. clamata* (medium) to eat it; we may infer therefore that the size of the object was responsible for the peculiar behavior on the part of both frogs. I noticed, both before and after this observation, that when frogs jump for small locusts, flies, etc., they land almost exactly at the spot on which the locust or fly is located. The large size of the locust seems therefore to have partially inhibited the feeding reaction. This inhibitory action plus the effect of the previous unsatisfactory jump at the locust resulted for *R. clamata* (medium) in almost complete inhibition of reaction. At the conclusion of the experiment the locust was removed from the cage.

August 1, 10 A. M.—The locust was again placed into the cage. *Rana clamata* (medium) became interested the moment the locust began climbing up the wall of the cage. In about a minute the frog, striking below the locust, brought it down with only its left hind foot in the frog's mouth. The locust freed itself easily. The frog made no further attempts to get it, nor was there any visible reaction to it for over an hour, although the locust was nearly always within easy striking distance.

Rana sylvatica was not observed to react visibly to a locust of such size, although it is just barely possible that the frog could swallow it.

August 1, 3 P. M.—I again placed the locust into the cage. There was no visible response on the part of any of the frogs. Nor was there any response to the hairy caterpillars which have been in the cage continuously since July 29. When I removed the caterpillars I found that none had been eaten except as recorded above.

August 9, 9.30 A. M.—The frogs have not been fed for two days. I placed one of the hairy caterpillars into the cage. Each of the four frogs in turn snapped up the caterpillar, but in every case extruded the tongue subsequently and shook the caterpillar off. Then the caterpillar was taken out of the cage.

August 9, 12.30 P. M.—The caterpillar was placed into the cage again.

Rana sylvatica reacted first by making two short hops to orient so as to look directly at the caterpillar. (The caterpillar was about 5 cm. in front of the frog). The head of the frog was then slowly lowered and brought forward toward the caterpillar, but I could not see that the tongue was shot out although I watched especially to see if this would happen. In a second or two the head lurched forward a little more and then the tongue was *very slowly* extended, barely touching the caterpillar. The tongue was now withdrawn and then suddenly extruded, with what appeared as a very slight attempt to shake the caterpillar off. The caterpillar elicited no further response during the next 45 minutes.

Rana clamata (small) and *R. virescens* paid no attention whatever to the caterpillar.

Rana clamata (medium) reacted visibly when the caterpillar was 10 cm. in front of it. See figure 1. The interval between the moment when I dropped the caterpillar in front of the frog and the initial reaction was about 2 seconds. The caterpillar was dropped on the edge of the board lying on the dish of water. The moment the caterpillar started crawling along the board the frog made three short hops, the last bringing it upon the board. Then, as the caterpillar crawled, the frog made three more short hops at intervals to keep up with the caterpillar. The frog then bent down its head and body seemingly for the purpose of looking more closely at the caterpillar. Next, there was a slight forward movement of the head, but I did not see the tongue come out although I looked closely. The cater-

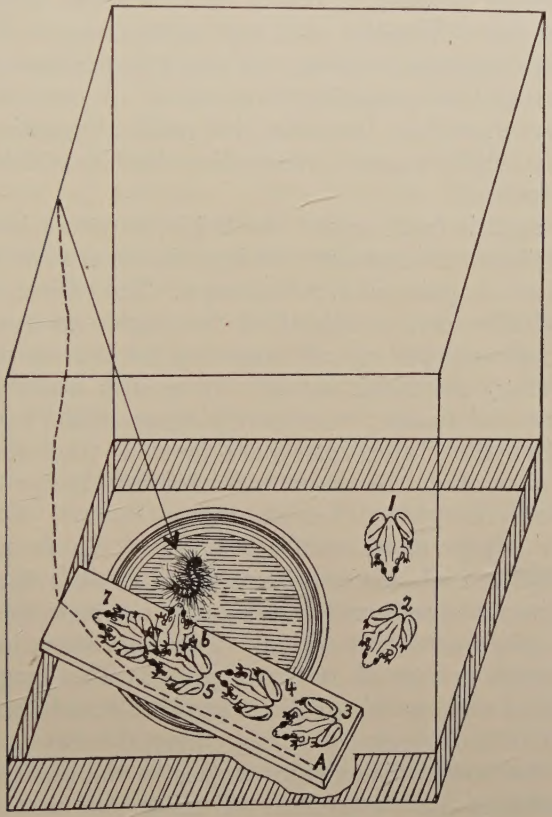

FIGURE 1. Sketch of the frog cage, as described on page 314, and frog, illustrating the behavior of *Rana clamata* (medium) while examining the hairy caterpillar. The numerals 1 to 5 indicate the successive positions of the frog while the caterpillar crawled along the board as shown by the line of dashes. After the caterpillar had fallen from the top of the cage into the dish of water, positions 6 and 7 were successively taken. The caterpillar was placed on the board at A. For fuller description see experimental record under August 9. Not drawn to scale.

pillar then crawled away without eliciting immediately any further response from the frog. The caterpillar kept on crawling to the end of the board and up the side of the cage. When it came to the ceiling, it lost its foothold and dropped into the water close beside the board on which the frog sat. The wriggling of the caterpillar as it lay on the surface of the water attracted the frog's attention. A short hop oriented the frog. After watching the caterpillar for about 10 seconds, the frog, with a very short hop, resumed its original position with the body axis at right angles to the direction in which the caterpillar was located.

On July 29 this frogf ormed the habit, in two trials, of avoiding crawling hairy caterpillars. It is probable that no hairy caterpillars were tried again till 9.30 August 9. The effects of the habit were not wholly lost, as might at first sight appear, when the caterpillar was snapped up on August 9, for it took only a single trial to perfect the habit again. It is also possible that the unusual state of hunger was partly responsible for the break in the habit. But, interpreting the facts as they stand, it cannot be denied that the habit of avoiding hairy caterpillars persisted to some extent for 10 days.

August 13, 5.30 P. M.—Since August 9 the frogs had been very scantily fed. I now put another caterpillar into the cage.

Rana clamata (medium) manifested interest in the caterpillar 5 seconds after introduction. Two very short hops brought the frog within 3 cm. of the caterpillar. The frog then bent down the head and examined the caterpillar for about 40 seconds. At the end of this period the frog jumped away 5 cm. to the right with the body axis at right angles to the position occupied while examining the caterpillar. During the next 30 minutes the frog did not respond visibly to the movements of the caterpillar.

Rana sylvatica took no notice whatever of the caterpillar.

Rana virescens hopped toward the caterpillar and then snapped it up, but immediately released it in the usual way. The frog took no further notice of the caterpillar.

Rana clamata (small) sat in the dish while the previously recorded behavior was observed. When the caterpillar was crawling again unmolested, near the dish, the frog hopped out of it, snapped up the caterpillar, but immediately released it by throwing out the tongue and shaking off the caterpillar in the usual way. In about 5 seconds the frog snapped up the caterpillar again and immediately released it. About two minutes later the frog snapped for the third time but missed the caterpillar. The feeding reaction seemed to be slightly inhibited. Seven minutes later the caterpillar crawled back and forth on a walnut leaf stalk stripped of leaflets located 7 cm. above the surface of the water into which the frog had in the mean time jumped. The frog oriented in the water to face the caterpillar, and then raised the head, watching the caterpillar for about 15 seconds. Then a house fly alighted on a piece of board 12 cm. away from, and 45 degrees to the left of, the frog. Immediately the frog oriented, and after a half second's examination, jumped and caught the fly.

This day's observations show that the habit of leaving hairy caterpillars alone was well formed by the experiences of August 9, for the unusual state of hunger occasioned by very scanty feeding since August 9 must have put the habit to a severe test. Nevertheless, two of the frogs, *Rana clamata* (medium) and *R. sylvatica*, withstood the test.

Unavoidable circumstances made it necessary to terminate this series of experiments with these observations.

Five months later certain experiments were carried on at Knoxville, Tennessee, with the *Rana clamata* (medium) of the preceding experiments, in a cage similar to that employed at Cold Spring Harbor. (The other frogs mentioned had escaped during transportation.) The observations from this second set of experiments confirm the conclusions drawn from the first series, and in a few instances new features of behavior are brought out. During the five months' interval various kinds of food were fed at irregular intervals. Flies, leaf hoppers, earthworms, and *Pieris rapae* caterpillars were the chief articles of diet.

In this series of experiments some food organisms which are usually eaten with great readiness were altered with chemicals and with electrical stimuli to make them disagreeable. Although such artificial changes are easily accomplished, the method is not as productive of results in feeding experiments as is the natural history method, chiefly because artificial stimuli, especially those proceeding from chemicals, are usually not as easily controlled as those naturally resident in an animal. When it is remembered that peculiarities of movement of a food organism may be a factor in discrimination, this consideration acquires added significance.

The *Rana clamata* was fed with an irregular succession of earthworms and mealworms (*Tenebrio obscura* and *T. molitor*) for a few days to determine whether either of these organisms is eaten with greater readiness than the other. After it was found that if any such preference existed, it was in favor of the earthworm, the earthworms that were fed henceforth were nearly all treated with oil of cloves or with calcium chloride. These chemicals markedly irritate the mucous membranes of the frog. It was thought that the frog would in time come to leave the chemically treated worms alone. The experiment was not entirely perfect in its technique because the oil of cloves and the calcium chloride caused the worms to behave abnormally.

These substances are very irritating to the worms, causing violent movements, and if the substances act for a few minutes the worm becomes paralyzed in the treated region; for this reason only the posterior parts of the worms were treated. However, since only confirmatory evidence was wanted—evidence derived from a method of experimentation different in nearly all respects from that employed in the first series of experiments—only the general results need be regarded. These proved to be satisfactory. The following is a summary of the results obtained from feeding the medium sized green frog with meal worms and an occasional chemically treated earthworm.

First day. I painted the posterior part of an earthworm with a little oil of cloves, and placed it into the cage. The worm wriggled less than a normal worm. The frog snapped it up in normal fashion. There was no indication that it experienced any disagreeable sensations.

Second day. 11.30 A. M. I painted several worms with oil of cloves and placed them into the cage in clear view of the frog. None were eaten or reacted to in any way for 5 minutes. I then put a small meal worm into the cage. This was eaten in 15 seconds. In a few minutes a chemically untreated earthworm was put into the cage. It was eaten in about 30 seconds.

Second day. 2.30 P. M. A worm painted with $CaCl_2$ was placed into the cage; it was not eaten. I presented in a few minutes a mealworm. It was eaten promptly. In a few minutes I painted a worm with $CaCl_2$ and put it in the same place where the mealworm had been picked up, but the worm was not eaten. The frog hopped away in three minutes. Another mealworm was eaten in 15 seconds.

Third day. I placed a worm treated with $CaCl_2$ into the cage, but there was no reaction on the part of the frog. A mealworm was then presented. It was eaten in 15 seconds. Then I fed an untreated worm. No reaction occurred in 5 minutes. I then fed a meal worm, which was eaten in one minute. In about 30 minutes an untreated worm was placed into the cage without eliciting any reaction on the part of the frog for several minutes. Then another untreated worm was placed into the cage. No reaction was evident for about 8 minutes. Then the worm happened to crawl away from the frog to the side. When it was about 10 cm. away, the frog made a very feeble effort to get the worm. I then caused the worm to crawl toward the frog from the side. When the worm was crawling under the frog's chin, the frog made another effort to get the worm, but missed it, getting instead a few grains of sand. As the tongue was withdrawn into the mouth the sand was scraped off on the jaws, from which it was at once wiped with the fore feet. The frog hopped away in a few seconds. I presented another normal worm. In a few seconds the frog became interested—shown by a slight side twist of the body—but another frog in the cage snapped up the worm.

Fourth day. 10 A. M. I placed a worm treated with $CaCl_2$ into the cage for over five minutes, but there was no response on the frog's part. I then presented another similarly treated worm. After one minute the frog made a very feeble effort to snap it up, but did not succeed. Since this worm became inactive I presented a third similarly treated with $CaCl_2$. After three minutes the frog made six feeble and unsuccessful strokes with the tongue, followed by a seventh strong stroke which brought the worm's head into the frog's mouth. When the worm was about one-third swallowed the frog began to jump about the cage rather violently, a peculiarity of behavior caused probably by the contact of the worm's body (treated with $CaCl_2$)

with the feet of the frog. (Former control experiments on other frogs showed that the skin of frogs is very sensitive to solutions of $CaCl_2$). The worm was not entirely swallowed. Sometime between 15 and 20 minutes after the worm was snapped up, the worm broke in two, the anterior third being swallowed and the remainder dropping to the floor of the cage.

Fourth day. 12 M. An untreated worm was presented to the frog. No reaction occurred in 30 seconds.

Fourth day. 4 P. M. I presented a worm treated with $CaCl_2$. The worm wriggled for two minutes unnoticed. I then presented a mealworm which was eaten in about 15 seconds.

On the fifth and sixth days no experiments were made.

Seventh day. A mealworm was eaten in five seconds. A worm painted with $CaCl_2$ was then placed into the cage. It crawled into a very favorable position. The frog bent down the head in about 45 seconds after introduction, apparently to look at the worm more closely. In a few seconds after bending down the head, the frog shot out the tongue, missed the worm, and got instead a few fibres of grass. In ten seconds the frog hopped away. I then gave it a mealworm which was eaten in about 20 seconds.

Eighth day. The frog snapped at, but missed, an untreated worm two minutes after it was placed into the cage. The worm crawled around the cage for 20 minutes without calling forth any response from the frog. A mealworm which was now introduced, was eaten in two seconds. A normal untreated worm was then put into the cage, but no change of behavior resulted. Another mealworm placed 15 cm. to the side of the frog was eaten in three seconds.

Ninth day. The experiments so far show the effects of disagreeable chemical stimuli. The object was now to test the formation of habits by using a disagreeable electrical stimulus. An induced current was employed. One electrode was connected with the pan holding wet sand on which the frog sat. The other electrode was attached to a very thin copper wire, the end of which was wrapped around the body of a cockroach in such a way as not to interfere much with the roach's crawling movements. The idea was that as soon as the roach should be snapped up, the tongue of the frog, touching the wire, would close the circuit, and a shock would then be sent into the tongue. The strength of the shock was determined by applying the electrode holding the food to the hind leg of another frog; a shock that was just strong enough to cause a reaction was then used on the medium-sized *Rana clamata*. But the electric shock turned out to be very much stronger in the mouth of the *Rana clamata* than on the hind leg of the test frog. The moment the frog snapped up the cockroach which had been placed into the cage, the frog immediately executed a series of wild hops until the roach was got rid of. The speed of the reactions prevented me from observing how the roach was brought out. Whether the frog actively threw it out, or whether it was pulled out by the elasticity of the copper electrode, I do not know. Other roaches were offered with and without electrode, but none were noticed.

Tenth day. Roaches, earthworms, and mealworms were placed into the cage at various times of the day, but the frog became interested in none of them.

Eleventh, twelfth and thirteenth days. No reactions toward any sort of food were observed.

Fourteenth day. One mealworm was eaten one minute after presentation.

Fifteenth to twentieth days. From one to three mealworms were eaten each day. No earthworms were eaten or even noticed.

The experiment with the electric stimulus has little value. The stimulus was unfortunately much too strong. This put the frog into a state similar to that produced by fear, and in consequence the eating instinct was wholly inhibited for a few days. It is of interest, however, to note that discrimination between mealworms and earthworms was not interfered with to an appreciable extent, excepting perhaps that discrimination was sharpened.

At the same time that the medium-sized spring frog was experimented on with mealworms and with earthworms chemically treated, a large male *Rana clamata* was also fed with an irregular succession of these organisms to determine whether the rapidity of habit formation varied markedly among different individuals of the species.

First day. (On account of the generally negative character of the results the mealworms which were fed are not recorded. From two to six mealworms were eaten each day.) An earthworm painted with $CaCl_2$ was presented. It was eaten at once. After it was down the frog rubbed his belly several times with his fore feet.

Second day. 11.30 A. M. An earthworm treated with $CaCl_2$ was presented. It was eaten at once. The frog rubbed his belly with both fore feet. I presented a small untreated worm. It was eaten in 30 seconds. Another worm treated with $CaCl_2$ was eaten in 30 seconds. The frog was then given a worm treated with oil of cloves. This worm was eaten in 15 seconds. The frog began to jump about actively seemingly trying to get under something. Finally he jumped into the water and remained there.

Second day. 2.30 P. M. A worm treated with $CaCl_2$ was eaten promptly. The frog's hind legs twitched a little; followed by a rubbing of the belly. Another worm treated with $CaCl_2$ was eaten promptly.

Third day. A worm treated with $CaCl_2$ was presented. It was eaten promptly. A worm dusted with powdered quinine sulphate was also eaten promptly. Following this I put normal worms into the cage, but for 10 minutes none were eaten. On three occasions the frog hopped away from the worms after seeing them for a minute or so. In about 30 minutes I placed a normal worm into the cage. It was eaten in a few seconds.

Fourth day. A worm treated with $CaCl_2$ was snapped up in a few seconds. After the worm was down the frog rubbed the point of his nose with the fore feet. Apparently some of the iritating $CaCl_2$ was brought into contact with the nose while the worm was being swallowed.

No experiments were made on the fifth and sixth days.

Seventh day. A worm treated with $CaCl_2$ was eaten in 10 seconds. The frog rubbed his belly. In two minutes another $CaCl_2$ worm was presented and promptly eaten. Again the frog rubbed his belly. There seemed to have been too much $CaCl_2$ for the frog seemed to try to get rid of the worm.

Eighth day. A normal untreated worm when placed into the cage was eaten in one minute. Another worm was not eaten in four minutes.

Ninth day. I attached one electrode of an induced current to the wet sand in the cage, and the other, ending in a very thin wire, to an earthworm lying on a small sheet of glass. The frog snapped up the worm, made several wild hops, and then dropped it.

Tenth day. Earthworms, mealworms, and cockroaches were placed into the cage, but none were eaten or even noticed.

On the eleventh, twelfth and thirteenth days nothing was eaten.

Fourteenth day. Three mealworms were eaten but there was no reaction to earthworms.

Fifteenth day. The frog ate two mealworms. Following these a normal earthworm was presented, but was unnoticed for ten minutes. Two more mealworms were then eaten in rapid succession.

CONCLUSIONS

The experiments cited illustrate the formation of a habit in at least five different cases as follows: *Rana clamata* (medium) avoided hairy caterpillars after at most four trials (the first two possible trials on July 26 may have had nothing to do with the formation of the avoiding habit); *Rana sylvatica* formed the habit in seven trials; *Rana virescens* formed the same habit in four trials, three on one day and one on the following day; *Rana clamata* (medium) learned to avoid chemically treated earthworms after two trials (after only one trial if the chemical effect only is considered); the large *Rana clamata* formed the avoiding habit only after a large number of trials, and then possibly only because an electric stimulus was employed; both the *Rana clamata* refused all food for three days after a single experience with the electric shock. It may be pointed out that in the case of *Rana clamata* (medium) the inhibition of the feeding instinct did not affect the habit of leaving alone earthworms and eating mealworms. With regard to the large *Rana clamata*, we cannot be sure whether the habit of avoiding earthworms and eating meal worms was established wholly by the single application of the electric stimulus, or whether the habit, already partly formed by the effect of the chemically treated worms, was only completed by the electric shock.

Little attention was paid to the persistence of the habits which the frogs formed. After the application of the electric shock no earthworms were eaten by *Rana clamata* (medium) for 11 days, although mealworms were eaten freely. In the first series of experiments the habit of avoiding hairy caterpillars persisted partially for ten days, for on the tenth day a single trial again perfected the habit. In this case the habit was severely tested by keen hunger resulting from lack of food for two days. The other frogs also showed the effects of the habit for similar periods of time. In the first series of experiments the hairy caterpillar was refused while more than twenty widely different kinds of insects, etc., were eaten. In the second series, earthworms were refused while mealworms only were eaten. Whether the eating of a large variety of animals tends to break down a habit of rejecting one kind sooner than the eating of only a single variety would, has not been determined.

The avoiding habits were formed in two different ways. First, the disagreeable object was taken into the mouth and then rejected, as in the case of avoiding hairy caterpillars. Second, the disagreeable object was eaten without any visible effort at rejection with the tongue. This involves no muscular efforts of a rejecting character. The habit is formed wholly in nervous tissue. Habit formation of this character is illustrated in the experiments with chemically treated earthworms. In the case of *Rana clamata* (medium) the habit of avoiding earthworms was formed on the basis of a single experience with a disagreeable earthworm, which was eaten without any apparent effort to eject it after it was in the frog's mouth, nor was there any muscular effort observed that was not present when a normal earthworm is eaten.

Although such a distinction does not seem to have been brought out before by students of animal behavior, the practical value of such a distinction is apparent, for in experimenting with animals, a habit might sometimes be thought to have arisen suddenly when as a matter of fact it may have been formed gradually and invisibly, and only made its appearance suddenly. This may be illustrated by referring to the behavior of the large *Rana clamata*. When did the earthworm-avoiding-habit begin to form? Was it when the first chemically treated earthworm was eaten, or was the habit actually initiated when the electric shock was introduced—the chemically treated earthworm previously eaten having left no effect? Further, such a discrimination enables us to conclude that actual trial with subsequent rejection in unnecessary for the formation of a habit based on the avoidance of a disagreeable object; trial only is necessary. This does not mean that the muscular act of rejection may not sometimes aid in strengthening a habit or in perfecting it more quickly.

With regard to the rapidity of the formation of a habit my results differ markedly from those obtained by Yerkes in his careful and extensive work on frog reactions. But our results are not contradictory, for Yerkes worked on habit formation by using the labyrinth and other devices, making use of what might be called for convenience the homing instinct; while my work is based on discrimination involving the feeding instinct. The apparatus Yerkes used in his experiments seems to be the simplest that could be devised which insured trustworthy results. One piece of apparatus was "a small box with an opening 15 cm. by 10 cm. so that the animal could escape from confinement in it through the opening, the lower portion being closed by a plate of glass 10 cm. by 10 cm. leaving a space 5 cm. by 10 cm. at the top." The frogs being placed in the box "tended to jump toward the opening because it was light, but they did not learn with 20 or 30 experiences that there was a glass at the bottom to be avoided." (11, p. 582.) Other experiments with a very simple maze or labyrinth showed also that from 50 to 100 trials were necessary to perfect the habit of correctly threading the maze. The question now arises, why should Yerkes' frogs require from 20 to 100 trials to form a habit, while my frogs required only from two to seven trials?

The writer is convinced that the solution lies in the fact that his experiments involved adaptations in a highly developed and plastic instinct (using this word here and throughout the paper in a general sense) that is exercised many times daily in the frog's active natural life, while Yerkes' experiments involved adaptations in a very simple, hard and fast, instinct. Undoubtedly situations frequently arise in a frog's wild life when a disagreeable insect or other food animal is tested and rejected. If the frog did not learn in a few trials to leave the disagreeable object quite alone—if the feeding instinct was as inflexible as it has usually (and erroneously, as I shall show at a later date) been supposed—the frog would be condemned to try the disagreeable food object at least 20 to 100 times, or perhaps indefinitely. Aside from the waste of time and energy which might otherwise be employed in getting food, there is the added danger that the disagreeable object may be swallowed accidentally. (Disagreeable foods are usually considered harmful.) It is therefore highly advantageous to frogs to learn rapidly to avoid disagreeable foods.

On the other hand, the occasions must be rare when a frog must hop over a transparent plate or thread a natural or artificial labyrinth correctly in order to achieve safety, or for any other reason. Such opportúnities could arise only when the young frog leaves the native pond in search of some other pond, or when the frog is compelled to leave the adopted pond on account of its drying up, or for other reasons. From this it follows that there could be little advantage in the ability to learn rapidly to thread a simple labyrinth. From the standpoint of natural history, such a capacity could hardly be considered as having life and death value; it would be merely an ornamental psychic quality.

These considerations lead to what the author believes is the real cause for the varying capacity of frogs to form different habits. The author believes that the difference is to be sought in the nervous equipment available in forming particular habits. The fact that the feeding instinct is very complex, involving many muscular actions and sense impressions all delicately co-ordinated, bespeaks, according to the commonly accepted teaching in such matters, an inherited neuro-muscular apparatus which at the first proper stimulus works effectively. For the green frog, and perhaps for all the others mentioned in this paper, perhaps no two stimuli are exactly alike, even in the whole life of the frog. Many sorts of insects and other animals are eaten in many different positions; so that the feeding instinct, although complicated, probably works extremely seldom in exactly the same way. Instead of being a stereotyped instinct or chain-reflex, the feeding mechanism is in reality very plastic, and the fact that it is plastic suggests what is in all probability the basis for the rapid formation of habits involving the feeding mechanism. On the other hand, the relatively long time required to learn the labyrinths of Yerkes is doubtless due to the absence of a neuro-muscular mechanism formed especially for learning rapidly a natural or artificial labyrinth.

We may suggest as a tentative hypothesis that a habit may be formed rapidly or slowly in proportion to the high or low degree of perfection of the nervous connections which are involved in the acts upon which a habit is established. Or, to interpret this from the viewpoint of present day verifiable fact, it may be said that *the greater the variety of situations which are successfully met in the natural life of an animal by a specialized neuro-muscular mechanism, the more rapid may be the formation of habits involving that mechanism.*

Although this conclusion is clearly supported experimentally only by evidence derived from a comparison of the rapidity of the formation of habits in frogs, much of the work on habit formation in other animals tends to confirm this view. We find the most rapid learning in those cases where experimental apparatus was especially adapted to a "peculiar facility" in muscular action of one sort or another. Thus, to cite an example, L. W. Cole was led to use problem boxes with fastenings of various sorts to test the intelligence of raccoons, for "the peculiar facility of the raccoon in the use of his forepaws and his tendency to investigate objects by touch suggested at once that he might learn readily to operate simple fastenings." (4, p. 212.) Cole's results seem to show that his raccoons learned more rapidly to operate fastenings than to perform correctly the sensory discrimination tests, although the latter involved fewer muscles and nerves than the former. The reason for the difference is probably that the neuro-muscular mechanism involved in undoing fastenings is more highly developed (specialized) than the mechanisms involved in forming sensory associations; or otherwise expressed, the former mechanism is used daily in the raccoon's active wild life, while that employed in forming the sensory associations is seldom employed.

This explanation of the variation in the rapidity of the formation of habits in the same animal differs essentially from the "prophecy" of Washburn and Bentley: "In general it may be prophesied that the more deep-rooted and essential the instinct appealed to by the 'experience' to which an animal is subjected, the more rapidly will the animal profit by experience" (10, p. 125).

I am uncertain of the meaning of "deep-rooted." If the early appearance of an instinct in phylogeny makes it deep-rooted and late appearance makes it less so, the meaning is almost wholly speculative, for we know next to nothing about the racial development of instincts. If "deep-rooted" is supposed to mean about the same as essential, discussion is facilitated, for it is assumed by biologists generally that all or nearly all instincts have life and death value either in ontogeny or in phylogeny, and so all or nearly all, are supposed to be essential. To illustrate: the "homing" or "safety" instinct is as essential to the average frog as is the feeding instinct. The frog, with little or no harm, can go for long periods (weeks and months together) without exercising the feeding instinct; but if the average frog should suspend the homing or safety instinct for the same length of time, it is doubtful whether it would escape its numerous enemies: hawks, owls, snakes, etc. Since both these essential instincts have been tested from the viewpoint of the rapidity of habit formation, and since it has been found that the feeding instinct is easily modifiable and permits of rapid habit formation, whereas the homing instinct permits of only very slow habit formation, we must conclude that the chances are strong that Washburn and Bentley's "prophecy" will, at least in its present form, remain unfulfilled.

POSITION OF THE FROG IN THE SCALE OF ANIMAL INTELLIGENCE

A majority, if not all of the students of animal behavior hold that one of the most important results to be obtained from a study of the behavior of animals is their arrangement in a system based upon their intelligence, such as has been done for animals with regard to their anatomical structure. Thus, in speaking of his experiments on the green frog (*Rana clamata*), Yerkes writes: "Other animals which were used gave results so similar to those for frog No. 2 that I feel justified in presenting the latter as representative of the rapidity with which the green frog profits by experience." (11, p. 588.) (The No. 2 referred to required between 60 and 110 trials to learn a simple labyrinth.) Again, "This very clearly shows the slowness of adaptation in the frog, in contrast with the rapidity of habit formation in the cat or chick." (11, p. 583.)

We have already noted what is the probable cause of the very rapid formation of habit in my experiments as compared with the slow formation of habit in Yerkes' experiments. We noted also that the feeding instinct in frogs is more characteristic and more highly specialized than the homing or safety instinct. It is quite evident therefore that if Yerkes based his conclusions solely upon the results of his experiments described in the paper from which the quotations are taken, such conclusion is made untenable by my results; but if Yerkes had in mind also the frog's position in the animal scale as compared with the other vertebrates whose behavior is known, as he doubtless did, then it is possible that his conclusion is not far from the true one. The fact that our results warrant us to estimate the rate of habit formation so differently is sufficient evidence that we are not at present in possession of sufficient experimental data to enable us to say with any degree of precision what rate of learning by experience is representative of the green frog.

The fact that habit formation may be very rapid while a certain instinct is being exercised, and very slow when another instinct in the same animal is exercised, makes it doubtful whether the placing of an animal in a scale of intelligence is of much scientific value if only a part of the animal's behavior is known. Thus the frog might be placed among the least intelligent of animals upon the basis of Yerkes' experiments, but if my results serve as a basis, then the frog might stand above the raccoon (4), the squirrel (12), the rat (3), the cat (1), and perhaps the dog (5), in all cases judging merely by the number of trials necessary to perfect a habit. It is clear then, that we are not in a position to classify an animal in the scale of intelligence from observations on its behavior in which only one or two specialized neuro-muscular mechanisms are involved; on the contrary, systematic classification cannot be considered accurate until all or nearly all the more or less specialized neuromuscular mechanisms have been investigated.

In comparing the rapidity of habit formation of Yerkes' frogs in the labyrinth with that of mine while feeding, it may be objected that a conclusion derived from such a comparison is not fraught with as much meaning as might appear at first sight, since Yerkes' frogs may be thought of as having acquired a habit of doing a new act—one added on—a positive habit; while my frogs learned *not* to do an act that they instinctively incline to do, a discontinuance of a habit or instinct already present—or a positive habit. This would mean that we are comparing processes which differ from each other, not in degree but in kind. While I admit that it is quite possible that it may some time be found to be easier for an animal to inhibit an action than to learn a new one of a similar sort, we have at present no experimental evidence to my knowledge that this is so. Further, our experiments with frogs may be discussed from the viewpoint of discriminative capacities. On this basis the frogs of Yerkes' experiments seem to have discriminated between degrees of light and dark in the first part of the labyrinth, while in the last part of the labyrinth they clearly formed the habit to perform certain movements (to get out of the labyrinth) and to avoid others which they instinctively might not avoid—the glass plate in the visually determined shortest path to the tank—that is, they discriminated between going straight forward and turning to the right or left as the case may have been. These habits were formed by dropping certain instinctive movements, just as the frogs in the feeding experiments learned to drop certain instinctive movements. The objection spoken of in the beginning of this paragraph therefore does not seem to deserve consideration until we have further data on this point.

It is hardly necessary, perhaps, to speak of instinctive avoidance of hairy caterpillars. C. L. Morgan seems to think that birds and lizards inherit, somewhat incompletely, the habit of avoiding warningly colored "caterpillars or insects." The inheritance is incomplete because sometimes the insects are eaten. "But a very small basis of experience, often a single case, is sufficient to establish the association" (7, p. 445). Whatever may be the explanation for the facts cited by Morgan, instinctive avoidance of hairy caterpillars by frogs probably does not explain the rapid formation of the avoiding habit, because it clearly cannot explain the more rapidly formed habit of avoiding chemically treated earthworms.

PSYCHIC PROCESSES

Can the experimental results described in this paper be satisfactorily explained upon purely physiologic grounds, or is it necessary to call in psychic processes to make the explanation adequate ?

Let us take first the case of *Rana clamata* (medium) which formed the habit of avoiding hairy caterpillars by testing with the tongue two caterpillars—possibly four (see record for July 26). The habit was formed very rapidly. Is it necessary therefore to assume the presence of concomitant psychic processes, such as mental images, for example, to explain satisfactorily how such rapid learning could be accomplished? It seems to be generally considered by animal and human psychologists that the very rapid formation of a habit, that is, one requiring very few experiences to form it, denotes a higher grade of intelligence (mental activity) than the slow formation of a habit.

Cases of very rapid learning sometimes appear when the stimulus is very disagreeable or even painful, in which case high intelligence is not necessarily denoted. For this is perhaps largely a physiologic reaction— a shock—usually causing cessation of general activity, inhibiting most of the normal activities of an animal, as is illustrated by the behavior of *Rana clamata* (medium) when stimulated by the electric current. Not only was the eating of cockroaches inhibited, but the ingestion of all food was suspended for several days. Therefore, this is not an instance of actual learning, for no discrimination resulted. Instead, all chance for discrimination was obliterated. It thus becomes a simple matter to decide whether very rapid modification of behavior is due to physiologic shock or to actual learning. If the application of a stimulus causes heightened discrimination, actual learning is indicated; if the process of discrimination is lowered or obliterated, physiologic shock is indicated. The behavior of the frogs toward the hairy caterpillars differs entirely from the reactions of the frogs to the electric stimulus, for the modified behavior affected only the caterpillar which gave the disagreeable stimulus. Compared with the strength of the eating instinct the caterpillars were only mildly disagreeable, for the frogs made several tests in quick succession. We have therefore to deal here with actual intelligence and not with physiologic shock.

Did the frog on seeing the hairy caterpillar, after the avoiding habit was formed, recall the previous disagreeable experience with it? Miss Washburn writes that "where the learning is very rapid this always remains possible." But "where the process is slower . . . . . the simpler hypothesis would be that the pleasure and pain of the results operate directly on the animal's tendencies to move, without the intervention of images" (9, p. 249).

We have examples in the foregoing observations which give us insight into the frog's method of learning to avoid hairy caterpillars, notably that figured for August 9. What took place in the frog's mind when the frog was actively following the caterpillar and closely examining it as it crawled; when the frog lost interest in it until after it had fallen into the water, and began to wriggle in a manner which presumably by its strangeness induced the frog to examine it closely again for a few seconds; and when it finally turned away? Was the frog "defining the construct" of hairy caterpillar, and perhaps also a "reconstruct" of the frog's past experience with it, to use Morgan's terminology, or does the frog's apparent examination of the caterpillar denote a vacillation of the eating and the avoiding habits, both striving, so to speak, to control its behavior? Examination from an objective viewpoint does not necessarily imply subjective processes; it may be purely or mainly a physiologic process. The apparent examination of food and other substances by the blue stentor when loops are made by the food particle in its pouch and funnel can hardly be supposed to be a psychic process (8). The elaborate and painstaking examination of empty mollusc shells, and other hollow objects, by a hermit crab, is, according to Brooks, also an instinctive or physiologic process, and little or no intelligence is indicated (2, p. 5). These instances are sufficient to show that the process of examination from a purely objective viewpoint does not of itself require psychic processes to explain it. The two cases can be explained as instinctive examination, similar to the accurately localized scratching movements of the hind legs of a decapitated frog when a drop of acetic acid is placed on the skin. But when examination results in intelligent choice on the basis of very few new experiences, such as has been seen in the behavior of *Rana clamata* (medium), the process of examining is probably of a psychic nature, for the known processes of physiology do not explain the behavior adequately.

We have seen also that extended examination is not caused by the mere presence of the hairy caterpillar, for its first appearance did not call forth examination. The real cause of the examining process is the experience which the frog had with the caterpillar. In the case of the stentor and of the hermit crab, the presence of the objects themselves were the cause of the examination; the previous experience with these objects did not change the examining process. Examination of the character described for *Rana clamata* (medium) is therefore not instinctive; it must be a psychic process.

This is as far as the writer wishes to go at present. It is all we can safely conclude from the behavior of the frogs as described in the early part of this paper.

We have seen that the rapid learning cannot be due to a shock received from a very disagreeable or painful stimulus; that the rejection of the hairy caterpillars is not instinctive; and that the extended examination of the hairy caterpillar is probably not a physiologic or instinctive process, but very probably a psychic one. I think that we can safely say that these points are established, at least in our working program. It now remains for us to give the psychic processes, which we have established by a process of elimination, descriptive names.

That part of the behavior of *Rana clamata* (medium) involved in examining the hairy caterpillar seems a clear case of defining of the construct of hairy caterpillar. Certain qualities, possibly movement was one of them, supplied the stimulus which under other circumstances would have set off the feeding instinct. In this case a peculiar crawling movement served as a stimulus (though perhaps not the only one) to construct a hairy caterpillar through association. Experience with hairy caterpillars taught the frog that such objects were to be avoided as food. When the construct of hairy caterpillar was defined to such a degree that association between it and disagreeable hairy caterpillar was perfect, examination ceased and the caterpillar was left. But after the caterpillar had crawled up the side of the cage and had fallen into the water, the frog's attention was again called to the " wrigglings " of the caterpillar, a quality of movement which the frog had not observed before in the caterpillar; hence, the construct of hairy caterpillar had to be revised by further definition. After the construct had passed from the vague to a final definite stage, can we say that there existed in the frog's memory a representation of the previous experience with hairy caterpillars? There is sufficient evidence here to justify us in seriously asking the question, but to establish such an important point the evidence ought to be overwhelming.

SUMMARY

1 Individuals of three different species of frogs, *Rana clamata*, *R. sylvatica*, and *R. virescens* learned to avoid disagreeable objects, such as hairy caterpillars, in from four to seven trials, or possibly less. Such habits persisted for at least ten days, but this point was not thoroughly tested.

2 A *Rana clamata* formed a habit of avoiding earthworms treated with chemicals in two trials. This habit persisted perfectly for only a short time, covering five trials in about 22 hours. The habit persisted somewhat imperfectly for five days. After an electric stimulus had been applied, earth-worms were not eaten for seven days although mealworms were eaten.

3 The avoiding habits were formed in two different ways. In the cases where the hairy caterpillars were avoided, active muscular rejection of the caterpillar accompanied each trial; but in the trials of the chemically treated earthworms, no rejection, nor any muscular action other than active swallowing of the food object was observed. The latter habit was formed entirely within nervous tissue.

4 The greater the variety of situations which are successfully met in an animal's life by a specialized neuro-muscular mechism (instinct, chain-reflex, etc.), the more rapid may be the formation of habits involving the mechanism.

5 Classification of an animal in the scale of intelligence is untrustworthy if based on observations of the behavior involving only one or two neuro-muscular mechanisms. To estimate correctly an animal's intelligence, for present purposes, we must know thoroughly the behavior involving all the important instincts and reflexes; later, less important behavior must also be taken into consideration.

6 Inherited instinct will not explain the rapid formation in frogs of habits of avoiding hairy caterpillars and chemically treated earthworms.

7 The rapid formation of habits, and the peculiar process of examination observed while the habits were formed, indicate intelligence of a relatively high order. The probability is that during the examining process the frog was "defining the construct" of hairy caterpillar.

REFERENCES

1. Berry, C. S. An experimental study of imitation in cats. Journ. Comp. 1908. Neurol. and Psych., vol. 18, p. 1.
2. Brooks, W. K. The foundations of zoology. New York. 1899.
3. Carr and Watson. Orientation in the white rat. Journ. Comp. Neurol. 1908. and Psych., vol. 18, p. 27.
4. Cole, L. W. Concerning the intelligence of raccoons. Jour. Comp. Neurol. 1907. and Psych., vol. 17, p. 211.
5. Hamilton, G. V. An experimental study of an unusual type of reaction in 1907. a dog. Journ. Comp. Neurol. and Psych., vol. 17, p. 329.
6. Loeb, J. Comparative physiology of the brain and comparative psychology. 1900. New York.
7. Morgan, C. L. Animal life and intelligence. Boston. 1891.
8. Schaeffer, A. A. Selection of food in Stentor caeruleus. Journ. Exper. 1909. Zool., vol. 8, p. 75.
9. Washburn, M. F. The animal mind. The animal behavior series., vol. 2. 1908. New York.
10. Washburn, M. F., and Bentley, I. M. The establishment of an association 1906. involving color discrimination in the creek chub, Semotilus atromaculatus. Journ. Comp. Neurol. and Psych., vol. 16, p. 113.
11. Yerkes, R. M. The instincts, habits, and reactions of the frog. I. Associative 1903. processes of the green frog. Harv. Psych. Studies, vol. 1, p. 579.
12. Yoakum, C. S. Some experiments upon the behavior of squirrels. Journ. 1909. Comp. Neurol. and Psych., vol. 19, p. 541.

NESTS AND NEST-BUILDING IN BIRDS: PART III

FRANCIS H. HERRICK

Western Reserve University, Cleveland, Ohio

Four figures

CONTENTS

6. Nidification: The Builders at Work. Nest-Building in the Robin. Choice of Nest-Site. Robin's Nest No. 1. Selection and Treatment of Materials. Molding and Turning. Alternating in Turning. Nest No. 2. Lack of Attunement in Instincts of the Male. Relation of Nest-Building to Egg-Laying and Incubation. Nest No. 3. Treatment of White and Colored Materials. Nest-Building in the Red-eyed Vireo. Building of the Oriole's Nest. Materials of the Oriole's Nest. Suspension of the Oriole's Nest. Nest-Building in Other Species: Chebecs, Bluebirds, Chipping Sparrows, Woodpeckers, Chicadees, Kingfishers, and Swallows. Cooperation in Nest-Building.
7. Intelligence in Nest-Building.
8. Origin of the Instincts of Incubation and Nidification in Birds.

In earlier sections of this paper we have tried to analyze the structure of the nests of birds in the terms of behavior in order to find a true basis for their classification, as well as to rightly weigh the significance of the variations which they present. We have seen that while protection is the prime function of the nest, the structure of the latter is but one of many variable elements through which the necessary protection of the species is secured.

It has been further shown that nest-building is one of a series of complex and correlated instincts pertaining to the reproductive cycle of birds, and that it is as truly ingrained as either the form or color of the egg, but this is not all; these serial instincts do not invariably proceed in due order and harmony. The chain is liable to weaken or snap at more than one point. The cycle may be normally repeated more than once in the season, and when begun it may be brought to a sudden close not alone through accident or fear, but by the rise of other instincts or by any disturbance which affects the usual rhythms. To such causes are due some of the most extraordinary phenomena of nests and nest life, such as the "cuckoo instinct," double, compound, or superimposed nests, the desertion of the last young, the late building or "repairing" of nests which come to naught, and to the "overlap" of instincts, which often leads to the most eccentric forms of behavior, such as pulling down feathers from the young or offering them strings or similar objects when the parent is prematurely seized by the building instinct, as explained more fully in earlier papers. We are now ready to consider what logically comes first, the actual building of the nest.

6. NIDIFICATION: THE BUILDERS AT WORK

After having criticised the literature of nest building, I wish to point out a difficulty with which all students, who must heed the clock, will have to contend. We are dealing here with a strictly field problem, to which the motto, "Strike while the iron is hot" admits of no exception; it is always "Now or never," and no part of the subject can be taken to the laboratory for leisurely study. In this latitude the best period for studying the building behavior of birds is from mid April until mid June. Accordingly, the student should be able to devote many successive days to continuous observation whenever the subject demands it.

In spite of such drawbacks, however, it would be difficult to name a field in the province of behavior where the right kind of study promises more interesting results the world over, and where some of the phenomena to be witnessed close to your door, may be as worthy of record as anything observed in the forests of Brazil or of Africa.

Without any doubt all builders of elaborate statant nests go through the molding and turning movements in a fairly uniform and stereotyped fashion, but it is safe to predict that all which fashion pendent nests, or which smooth or garnish the walls of their homes, especially when the sexes cooperate effectively in the work, will prove well worth watching.

Nest Building in the Robin.—The American robin of the eastern states (*Merula migratoria* or *Planesticus migratorius*) is an excellent exponent of the builders of statant nests of the increment type, molding a perfect cup of characteristic form and size, and commonly using mud or wet earth in such a way that a consistent mortar is produced. When sun dried and securely placed such nests long outlast the season.

Choice of Nest Site.—So far as I have observed, the selection of nesting site is a simple affair, and unattended with any important ceremonial in the robin, but I am unable to speak with any definiteness upon this point at present. Howe[37] believes that the female chooses the site, and this view is probably correct. He says that once when attention was called to a female robin in the crotch of a cherry tree, "she flew to the ground and began chasing about a male, evidently her mate. In a minute they both flew to the crotch which she had just left and stood peering about; the male flew to the ground again in a few seconds and the female also flew, returning in a minute with the few first twigs that were to form the foundation of the nest." When the case is not urgent, the choice of site is probably not so promptly made as is here implied. This is certainly true in bluebirds and house wrens where the simple proceedings can be more readily watched.

The blond ring dove, according to Craig,[38] in deciding upon a nesting site tries a number of promising situations, and "either bird, upon finding a likely spot, gives a nest-call which stimulates the mate to fly towards the source of the sound. . . . When at length a site is agreed upon, the selection is impressed upon the minds of the birds by a ceremony in which both sit together in the chosen spot and call and caress one another for a long period."

In the records of the building pairs which follow, those of the two last observed will be given first, because in certain respects more complete.

Robin's Nest No. 1.—This nest, when first noticed on June 14 at 2.30 P. M., consisted of a few wisps or weeds and rootlets laid on the horizontal limb of an elm, 10 feet from the ground, and at a point where a secondary branch made a flat crotch. This site had been selected presumably but a short time before; at any rate the work of building had only fairly begun.

Selection and Treatment of Materials: Molding and Turning—The female came repeatedly with fresh materials in her bill, and executed the following movements: alighting on the branch about a foot from the actual nest site she would pause a moment as if for assurance, trip up to it, drop her load and immediately set to work. She would first settle low down and press with her breast against the insignificant and incoherent mass of materials gathered, applying the pressure mainly by scratching movements of the feet, with wings half spread and vibrating, the tail pumping and usually depressed, while the whole body shook from the violence of the effort exerted. Such a complex series of movements involving the entire body so far as the skeletal muscles were concerned, we shall call a Molding Movement or simply a "mold." It is a "stamping" movement with the use of the breast as form, and commonly lasts from five to ten seconds, according to circumstances. The bird then rises, turns through an arc of six or seven degrees to the right or left; this we shall call the Turning Movement. She then settles as before and applies the next mold, and these acts may be repeated for the twentieth or fiftieth time, when from two to four complete revolutions are described by the body of the turning bird. These turning movements are all commonly in the same direction, that is if the robin makes the first turn to the right, this direction is continued to the end. Exceptions to this rule will be given later.

---

[37] Howe, Reginald Heber. Building Habits of the American Robin (*Merula migratoria*) in Eastern Massachusetts. The Auk, vol. xv, p. 162-167. New York, 1898.

[38] Op. cit. p. 93.

When this robin came with a second load precisely the same motions and behavior were repeated with one exception; if at the first visit she turned to the right, at the next she swerved to the left. In this case there was perfect alternation of turning movements, whatever the interval spent either at the nest or away from it This remarkable fact will be discussed a little later.

Aside from the molding, turning and alternation observed, another and very different characteristic of the building robin is to be noted; I refer to the Arrangement of Materials with the bill. After depositing upon the site what has been brought, the bird disposes of the material in a rather definite way, or at least in a manner to produce definite results. Not only are the straws, weeds and the like drawn from without inwards to prevent loss, but later, as we shall see, there must be a definite disposition of the mud and stubble in order that a cup can be modelled and a serviceable mortar produced.

To revert to the molding process; the scratching movements of the legs are often very violent from the first, and the sound of the claws on the bark of the limb can be distinctly heard at a distance of several yards, even after the work of building has gone on for hours. Indeed, so great is the violence of these motions that often the tendency at first is to scatter rather than consolidate the scanty materials; in a word the peculiar molding movements seem to be begun before they are needed. We shall later see that this is only partially true, and that it is through these very movements that the nest is firmly secured and adapted to its site. In molding, the head and wings usually go up, and the tail down, as already remarked, but the tail is sometimes held vertical when the bird rests upon its fore breast and neck. While watching nest building in this species on a former occasion I thought that the wrists of the wings were used as an aid to the bill in drawing the materials up to the body, but it was not the case in this instance. Movements of the wings and tail simply partake of the general movements of the feet and body, and evidently serve for balancing; at times such a bird seems to be almost standing on its head.

At the intervals between the molds the robin uses her bill quickly and decisively in drawing in towards her breast the loose or overflowing materials, often indeed with a violent snap of the bill, and this bird was seen to snap viciously at the leaves which overhung the nest and stood in her way. After the first hour or so of building there may be as much stubble on the ground as on the nest site, but this is not always the case; such waste material is invariably neglected when on the ground, but if hanging from the limb it is frequently, though not always, the subject of special attention, and is drawn into the nest. With this partial exception every increment is used as it is brought, and there is no sorting of materials or discarding what is once chosen. The molds often follow so rapidly that it is difficult to count them, the interval between each being limited to the time required by the bird to rise, turn, and settle again. Then long pauses may occur, the bird sitting low, and remaining quiet as if resting from fatigue. Later in the course of the process when the walls have risen, these pauses become still more pronounced, when the robin seems to be trying "the fit" of her nest, or to make the molding process more effective. In this case the male took no direct part in nest building, and the female always worked alone, and as a rule in perfect silence. An air of secrecy characterizes all the movements of the pair, especially of the female from the beginning, broken only by the guarding instinct which is strongest in the male. This guarding, moreover, begins at the time the nest site is chosen, before the building operations have fairly begun, and reaches a climax when the young are ready for flight.

If the building female is disturbed at any point in her work, she usually comes to attention, putting up her head, as if listening; then, it may be, she gives the alarm call, when the male who is close at hand, immediately responds, and appears on the scene ready for any emergency; for a moment the mask of secrecy is thrown off. The observer soon comes to be disregarded, if he remain perfectly quiet, whatever his position, but let him drop his pencil and stoop to pick it up, or make any unusual movement, he is detected at once; the worker sounds an alarm, makes a feint at flying straight at him, but swerves when within a few feet of his head, and goes off for more straw or mud. Nothing seemed to escape the vigilance of this guarding male, and whenever another robin or any strange bird trespassed on his preserves, it was immediately assailed and driven off with such outbursts of fiery pugnacity that it was fortunate to escape.

The Selection of Nest Material.—During the period of observation at this nest it was noticed that the materials were drawn from four different points, now from one, now from another, stubble, including dead grass and weeds from a field a few hundred feet away, the grass being occasionally pulled up by the roots with a considerable amount of adherent earth, mud from two points along a neighboring creek, and rootlets, dead weed stems and the like from a ploughed garden close at hand. While the female worked the cock stood quietly on guard, either in the nest tree or in another close at hand. When the work of a given visit was over, she would draw up to attention, pause, and fly low, closely accompanied by the male, to one of the points in question. Both on her departure and return the female usually took the lead, the male flying after her or abreast, and often within a few feet; but less commonly while keeping to her direction he would be farther to one side or in the rear. Alighted on the ground the pair would hop along together, the female making sundry dabs with her bill until a load was gathered. The general impression conveyed is that there is no hesitation as to where to go or what to get, any more than there is as to the treatment of materials when obtained. As a rule there is no fussing with the substance chosen though of course attempts to dislodge things often fail. The business throughout appears to be conducted with the utmost promptness and dispatch, with no suggestion of indecision or deliberation; indeed, it often seems as if every movement were necessary and predetermined. This, I say is the general impression conveyed after many hours of close watching; on the other hand, a robin will now and then make a tentative stab at the ground with no result, or having taken a weed or bunch of grass, will reject it, but this seldom happens, and may be determined by the influence of the male at the moment, who has perhaps moved to another point, or by some other element in the situation, such as the appearance of other birds.

It should not be inferred that there are no diversions or distractions while material is being gathered, for there are many; now the work progresses uniformly and rapidly; then it will vary or lag. These delays, in my opinion, are mainly due, to other causes than failure to search in the right places or to discover the proper substances. The effervescent character of the most potent instincts in birds, as in mammals, is very marked at all times and may be witnessed in every phase of the reproductive cycle. Thus, a bird when its young are assailed, and after it has displayed great pugnacity, and sounded its most emphatic alarms, will suddenly quiet down and calmly preen its feathers, as if nothing had happened, before another outburst ensues. We have seen that in nest building the aim to protect the site by concealment and secrecy is predominant, and delays in gathering the materials may be caused by the inhibiting presence of other birds, or by the distraction of food, which the builders naturally find in their customary methods of search. Hunger undoubtedly checks nest building at many points, and may be the cause of much of the delay observed.

In some cases the male will pick and dab at material as if in imitation of the female or in satisfaction of a feebly developed instinct, but in this instance, as we have remarked, the cock brought nothing to the site. In returning to the nest the female starts first and usually keeps the lead, the cock following close behind or abreast as before, he going to the place where he stands guard, and she to a point on the limb which habit soon defines, commonly a foot or more from the nest. Drawing up to attention, she pauses a moment as at leaving, holding high her straw or ball of mud; then if reassured she trips nimbly to the site, drops her load and goes to work.

At this nest the hen, when gathering material, and presumably while feeding, as well as when at work, was under the constant surveillance of the cock, and as suggested earlier (see part I, p. 180), she is stimulated to her task by the degree of ardor which he displays. The frequent singing of the male, while his mate labors in the field or at her nest is a clear signal that all goes well. As we shall later see, the male robin may take a hand in nest-building, or possibly even bring food to the nest (see p. 346), but his function is in the main complementary to that of the female, and his chief rôle that of guardian and incentor to action.

Wet weather, unless too prolonged or too violent (see Part I, p. 261), is no bar to the building robins, but the time of building is not a matter of choice and is independent of the weather. The mud which they employ to such good purpose, is taken direct from the ground where of the right consistency. The mud is brought in the mouth and is necessarily mixed with a certain amount of saliva, though usually in the form of a ball held in the bill; these balls must be worked over to some extent at the point where they are taken from the ground, and are sometimes as large as a walnut. I have seen the holes left in the soft mud from which balls have been removed, but have never been able to watch the working process, if there be any, by which they are extracted and removed.

While watching this robin, I once saw her leave the nest as if the work of the visit were over, and step out on the branch, when in a moment she wheeled about, returned and continued to mold as before. At other times I have often seen a bird pick up in this way stray materials and return them to the nest. Again this bird, the molding process over, would hop to the branch, uplift and stretch both wings together, until they nearly touched over the back; when working with mud, the builder, will fly into a tree and rub its bill clean on a branch before setting out for a fresh load.

Operations at this site ceased at 6.16 P. M. on the first day, shortly after sun down. Although the work had lasted for nearly four hours, inspection showed that virtually only a beginning of the foundation had been made, more material at that time lying on the grass or hanging below the level of the bough than actually resting upon it. Yet it is important to notice that with all the molding and turning movements repeated hundreds of times with the stubble and mud employed, two things had been accomplished, which probably could not have been done better in any other way; an adherent foundation had been laid, and compensation for the natural inequalities of the site had been properly made. Had the nest branch showed a much greater incline (compare the hummingbird's nest, fig. 16, Part II), this compensation would have been all the more marked. It is plainly apparent that the adjustment of the nest to its site is a gradual process, and must mechanically follow as a result of the molding and turning movements. It calls for no planning or reasoning powers whatever, but begins with the laying of the first straws, and is completed with the finish of the last mold. Another question involved is the disposition of material, which will be considered presently.

On the second day (June 15) observations began at 8.26 A. M., when but little change was apparent in this nest. During the first hour, eight visits were recorded, in course of which mud was brought seven times from the creek, and stubble from the garden once. At this time a rising nest wall began to be apparent from my position, and my attention was then directed to the alternation in the turning movements already referred to. The ten visits which followed, all of which I was able to record without interruption, are given with other pertinent data in Table VI.

Alternation in Turning.—It will be seen that there was perfect alternation in the direction of turning, even when the time spent away from the nest lasted 24 minutes, a fact which cannot be attributed to chance. The number of molds made at each visit varied from 23 to 53, and the number of complete revolutions described from two to four. The time spent at the nest lasted from 2½ to 11 minutes, and the time away when searching for material or otherwise engaged from 1½ to 24 minutes.

As the table indicates, both dead grass and stubble as well as mud were used at this time, but an examination of the nest

TABLE VI

ACTIVITY RECORD OF BUILDING ROBIN, ILLUSTRATING MOLDING, TURNING AND ALTERATION

No. of visit	Time of visit	No. of molds at each visit	Direction of turning	No. of revolutions described	Materials	Time at nest in minutes	Time away from nest
1......	9.33½	23	L	2—	Mud	3	1½
2......	9.45½	41	R	3+	Dead grass	2½	12
3......	9.51	27	L	2	“	3	5½
4......	9.58	27	R	2	Mud	3½	7
5......	10.4½	38	L	3	?	4	6½
6......	10.10½	53	R	3½	Mud	6½	6
7......	10.34½	52	L	4	Weeds	7	24
8......	10.45	56	R	3	Dead grass	7	10½
9......	10.48	48	L	2½	“	11	3
10......	11.02	—	R	—	—	—	14

showed only wet mud on the inside of the cup, the walls of which had risen to a height of nearly two inches. It is thus evident that the materials are not treated indifferently, but that at a certain stage the plastic mud is centrally placed, and the pressure so applied that it is pressed outward and downward into the interstices, thus engulfing weeds and stubble, and thus producing the mortar referred to above. This mortar is thus an incidental product of the molding process, for whatever the disposition of the soft mud its mixture with the other materials would be inevitable. The form and symmetry of the cup however, is dependent not only upon the molding and turning, but upon an effective distribution of the materials by the bill. If such a nest were incinerated, the clay cup only would remain, smooth and regular within, but outwardly drawn into irregular processes representing the interstices of the parts removed.

Not a spear of grass was to be seen on the inner wall of the cup at this period, nor was I able to tell from the appearance or feeling of the wet clay whether this bird had last turned to right or left. There is no twist of the body in molding, and the smoothing which is effected, as already noted, is due to successive “stampings” of the breast upon yielding materials. It is not therefore probable that the bird receives any clue to turning direction through the tactile sense. The tendency to alternate may pertain to the inherited nervous mechanism, and it is certainly more pronounced in some individuals than in others. Whenever the cock takes a hand in building, it would be interesting to ascertain what effect, if any, his movements may have upon the female, or if she in turn is influenced by him, but the matter did not receive attention early enough to settle this point.

Nest No. 2.—At a second nest observed at approximately the same place, time, and stage, 14 visits were recorded in the course of one hour and eight minutes. The female in this instance worked with greater rapidity and conditions were not so favorable for close scrutiny. So far as could be ascertained the number of molds at each visit seldom exceeded eight, the number of revolutions two, the time occupied varying from 1½ to 3½ minutes. Alternation in the direction was not so regular and ran as follows: R, R, L, R, L (R), R, L (R), L, R, L (R), L, R. R, L. Four breaks occur in this chain, and a peculiarity to be noticed was that on three occasions the bird after turning to the left (L (R)), finished by reversing and making two or three molds to the right.

Lack of Attunement in Instincts of the Male.—At this nest the male seemed to be lacking in ardor, for although his alarm was frequently heard, he did not so closely and persistently follow his mate. This impression was further confirmed by the following curious incident. While the female was engrossed with her work at the nest this male brought a cherry, but she slipped off without paying him heed. The cock, however, landed on the nest, and in a disconcerted manner dabbed at it several times, or at least lowered and raised his head, while still holding to the cherry, which after he had sounded an alarm, was carried away. No food was seen to pass between the pair, and since one was in plain view of the other, such conduct seems to be plainly due to a premature development of the instinct to feed the young, and to be strictly comparable to that of the bluebird to be noticed later (see p. 367).

To return to the first nest: this was essentially completed on the evening of the second day, by the addition of fine dead grass. The rim, though commonly firm and smooth, remained in this instance thin and weak. The character of the nest rim undoubtedly results from the regular movements aided by the arrangement of the materials effected by the bill, as already described. A little green grass was further added to the lining of this nest on the morning of the third day (June 16), when for the four days which followed it appeared to be deserted, but this was not the case, for though never actually seen in their tree, these robins were detected at a distance on more than one occasion. The first egg was laid at about 3.30 P. M., June 19. Towards the close of nest-building operations, as already noticed the intervals of rest between the molding movements became more and more prolonged, until the bird would sit quietly for a longer and longer space, as if resting or trying the "fit.' Now when the need of a nest is urgent these periods of rest are probably further lengthened until the bird remains to lay her first egg. We shall later see how in some cases, as in chipping sparrows, the molding movements seem to shade off into the practice of sitting in the nest, when finally the first egg is laid and incubation begun (see p. 366). In this instance incubation was not regularly established until the appearance of the second egg which was laid at about noon on the following day (June 20).

Nest No. 3.—The building of the third nest occupied, according to my estimate, 23 working hours, and represented 218 loads or increments, four-fifths of which were delivered by the female. Over 4,000 molding movements must have been made in shaping the nest-cup. An account of the operations at this nest has been given in another place and only a few facts need be referred to here. Both male and female worked on the first day for a period of about five hours, and at the rate of one load every 3½ minutes; this activity gradually slowed down and with the female only engaged, the average rate of delivery on the second day was once in 7½ minutes, and on the third once in 13½ minutes. With this abatement of building activity a new habit was gradually developed on the third day, that of sitting quietly in the nest for longer and longer intervals. As was suggested above, these resting intervals possibly become increased until the bird stays to lay her eggs, and finally to incubate them, especially when the need of a nest is urgent, but as also noted, several days may elapse when the nest is seldom visited. Many minor details of interest were noticed at this nest, but on the whole the behavior was precisely similar to that already described. In point of time this nest was the first to be studied, when unfortunately our attention had not been directed to the alternation in the direction of the turning movements already discussed.

Treatment of White and Colored Nest Material.—When this nest was first noticed a quantity of red, white and blue yarn, in addition to white hens' feathers and strips of white cotton cloth were strewn over the ground and suspended from poles in the vicinity of the nesting tree. In less than ten minutes the female robin went after the white yarn and brought two large loads of it in succession to the nest site. Cedarbirds have repeatedly taken yarns of all colors, indifferently, and worked them into what became very gaudy nests, but these robins disregarded all but the white, of which they carried seven loads to their nest on the first day taking it only off the ground. This yarn was cut into one and two foot lengths, and the manner in which it was treated proved interesting. The first white streamers were brought by the female, and after the usual molding movements, were left hanging from the nest branch. After stepping out of the nest, she detected them at once and seizing them with her bill, tried ineffectively to pull them on to the site, molding and turning as before. Returning immediately with more of the yarn she stood on the nest and tried to draw in the threads with her bill, but after much effort accomplished little, for the ends were still hanging free. Shortly after this the male dropped to the garden plot, gathered up several white strings and bore them to the tree, where they brought him up to a short turn by catching on a stub. He at first tried to release them by facing the nest and putting his whole force into a lateral strain. Failing in this he faced around and pulled; failing again, he advanced and taking up a little of the slack pulled again. I suppose no one would deny that intelligence was displayed in this act, but it should also be noted that his intelligence did not carry him to the point of going to the obstruction and actually freeing the thread. In this instance the yarn was released, but in others it held fast and there remained when the nest was completed.

It was noticed at this nest that when the male sounded an alarm the effect upon the working female was sometimes merely to cause her to sit quietly for a few seconds, but this evidently depended somewhat upon the pitch or quality of the sound, for a similar alarm from another pair of robins elicited a loud and emphatic *tseet*, although she did not desist a moment from her labors. While watching these birds I sat at a distance of about ten feet with a rain cloak drawn over me. As in the former case noticed, so long as there was no movement all went well, but if an arm was inadvertently moved, the worker would stop at once, squeal out her alarms, and dart hurriedly away; yet, as before, in a moment she would return with a fresh load of mud or straw. As at a former nest described there was a long lull in the building operations at about noon, varying from one-half hour to an hour.

On the morning of the fourth day this nest appeared perfect, and thereafter for two days, visits to it either for the purpose of adding fresh materials or for sitting must have been very infrequent. In short it appeared to have been deserted. It was begun in the afternoon of June 24, and at noon on June 28 the female slipped off quietly after laying her first egg. On the next day, June 29, she was seen at nine o'clock sitting quietly in a neighboring tree, waiting evidently for an opportunity to enter her nest unobserved; at 10.48 A. M. she was on the nest and upon leaving at 12.06 P. M., one hour and eighteen minutes later, the second egg had been deposited. Leaving her nest voluntarily at this time she was seen to go to the garden for food. Six minutes later she was at the nest again, and there remained with only brief forays for food, lasting from three to four minutes; incubation had regularly begun. The third egg which formed the complement, was laid between the hours of 10 and 11.30 A. M. on June 30.

In the robin, incubation lasts from 13 to 14 days, and is performed wholly or almost wholly by the hen, and during this period no building material is ever added to the nest, so far as observed. I have seen this bird leave her nest for food in early morning, towards noon, as well as in late afternoon, but only for intervals varying from a few seconds to a few minutes. Once at 5.30 P. M. during a pouring rain storm the drenched sitter was seen to leave abruptly and fly four hundred feet to a garden where she was met by the male. No food was seen to pass between them, and she returned after an absence of $2\frac{3}{4}$ minutes.

After the second day of incubation a habit of sitting with the head turned in a definite direction was formed and maint ined with scarcely any deviation for two weeks. This habit is evidently determined by the method of entering the nest, and the bird faces the direction of easiest approach, where vision is least interrupted.

According to Howe[39] the time occupied by the building robin varies from 3 to 15 days, according to need and other conditions, with an average of six days in the eleven nests observed. We shall not refer to his brief description of the process of constructing the nest for we consider it faulty at nearly every point.

Nest-Building in the Red Eyed Vireo.—We have frequently referred to the exquisite pendent nests of the red-eyed vireo (*Vireo olivaceus*), which are always suspended between the forks of a slender twig (see Part I, fig. 9), and we have seen that however diverse the materials employed, the form and dimensions of the cup are remarkably constant (see Part II, p. 268).

The nest of one of these vireos,[40] the building of which was watched from the vantage point of a window has also been described (see Part II, nest No. 3, table III, p. 269); it was begun at the fork of a maple twig, about 10 feet from a dwelling house, and 20 feet from the ground; when first noticed on May 30, at 1.30 P. M., it consisted of a minute mass of gray bast and spiders' silk bound to the angle of the crotch.

In building the statant nest, as in the case of the robin, the materials, of whatever sort, are simply brought and laid upon the site, where under the control of the bill they are subjected to the molding and turning movements, which begin promptly and cease only with the last finishing touch. Pendent nests characteristic of vireos and orioles could never be built after this method. With all such the work necessarily begins with securing the first fibres to those chosen twigs destined to support the nest. These fibres, moreover, represent the margin and side of the future nest close to the angle of the fork. A loose free-hanging mass is first formed, and this is gradually extended on either side downward and outward from the crotch. (Compare figs. 19 and 20.) A rim and bottom are gradually produced, and the remaining gap finally bridged at the side opposite to that represented by the first hanging mass.

---

[39] Op. cit. p. 164.

[40] For the opportunity of studying this nest I am indebted to the kindness of Mrs Robert E. Ruedy, Cleveland Heights, Ohio.

The first threads are wound around definite twigs and form what I shall call the *primary points of support*. Much labor is bestowed in building to the primary nest mass; secondary points of support are added later, when more than two twigs are used, for the suspension proceeds *pari passu* with the growth and conformation of the free mass. In the vireo these processes of building downward and adding new fibres to the support continue for a long time before much progress seems to be made, and it may be two days before a single molding movement is observed. Moreover, the vireo's molds are somewhat different from those practiced by the robin (see p. 353).

This vireo's nest occupied 4½ days in the building, and with the exceptions to be noticed later was the work of the female alone. It was composed of hundreds of minute increments, like a single bast fibre or bit of cocoon silk, some indeed so small that it was difficult to discern them at a distance of ten feet, even with aid of a glass. The record of a single hour's work at this early stage of operations is given in table VII. During this period visits were made by one or both birds on the average of once in every 4½ minutes. A light gray fibrous mass about one inch long and extending over each fork to about the same distance, had now been loosely secured beginning a little way from the angle of the twigs. It was composed of spiders' silk, chiefly from their egg cocoons, and fine bark strippings.

The female vireo in this instance took the lead and did all the constructive work, although the male frequently escorted her to and from the nest, and twice was seen to offer material which the female quickly took from bill or mouth. The fibrous matter brought was sometimes passed around the twigs, but always carefully incorporated by quick movements of the bill with the suspended mass, and from half a minute to a minute was usually spent in this work. The bird moved quietly and effectively, more time being spent in the readjustment of old material than with incorporation of the new. A very characteristic movement at this stage was to pick up the free end of a fibre, pass it over the twig and quickly secure it with the bill. Twice I saw this bird bring in a wisp of spiders' silk, and after getting it under one foot, draw out its fibres repeatedly with her bill, and not only pass them over the twig, but secure each end in succession to the nest mass. This silk was commonly carried in the mouth, and in such small quantities that none showed when the bill was closed. It was withdrawn wet, and when thus engaged, the bird would at times open her mouth very wide, as if the more readily to be rid of it. The saliva in this species has no marked viscous character, but possibly aids slightly in the treatment of the materials used. Many no doubt would describe the act of pulling out the silk as "deliberately spinning a thread" for a definite purpose. I regard it as strictly analogous to stripping bark and pulling at the frayed ends of any fibrous material, with the exception of the use of the foot, which is so unusual in passerine birds that it may be simply the result of individual experience; the use of the mailed foot in all preying species like the eagle and hawk, whether for striking, seizing or holding is primarily instinctive.

The song of the male vireo was often heard during the entire progress of nest-building. Twice only, as already noted, was he seen to bring building materials, and twice he came up behind the female and pecked at her as if in admonition to hurry the work. A somewhat similar observation has been recorded in the European swift. At a very early stage the female would try to sit on the beginnings of her labor, but the loose fibrous mass could not of course hold her, and dropping down she would always catch with spread wings on the V-shaped crotch. These attempts were frequently repeated until on the second day she was able to hold to the structure and press with her breast against its thin wall. It was common to see her stand at the angle and reaching far down peck daintily at the loose mass, fixing a fibre here, securing another there, but always working rapidly and as we say without "hesitation."

During the first day of this vireo's work the most striking facts noted were as follows: (1) winding silk and fine bast over the twigs at points about an inch from the angle of the crotch; (2) building downward upon these a loose mass of fiber, perfectly secured but having no resemblance to the future cup-shaped nest; (3) carrying the suspension forward, and downward and outward at either side of the nest-mass, which gradually takes the form of a half cup-shaped wall, and (4) finally attempting to rest in the " nest " and use the breast as form long before it was physically possible to make the movement effective. No turning movements were attempted at this early stage and there was no drawing of materials to the breast, but the conduct is otherwise suggestive of the robin's. There is the same scratching with the legs in bringing the breast to bear, but the yielding nature of the pendent mass renders such movements less effective.

At the beginning of observations on the second day (May 31), at 10 A. M. little change appeared in the nest mass or "half-cup"; the line of suspension had been extended about one inch and a half along either twig, and though quite open on the side opposite the angle, the nest-bottom had been partly framed in with bast. Ten visits which immediately followed are described in table VIII, and may be taken as a sample of the activities at this stage.

TABLE VII

Illustrating Building Activity in the Red–Eyed Vireo. First Day (May 30)

No. of visit	Time of visit	Birds at nest	Birds at work	Material	Remarks
1.....	1.30 p. m.	Male and female	Female	Cocoon-silk	Female only, with material.
2.....	1.32	" "	"	"	Female only, with material.
3.....	1.36	" "	"	"	Male brings cocoon-silk in mouth and gives it to female.
4.....	1.38	Female	"	"	
5.....	1.44	Male and female	"	"	
6.....	1.47	Female	"	?	
7.....	1.49	Male and female	"	Bast fibre	Female takes a little cocoon silk from bill of male.
8.....	1.51	" "	"	?	
9.....	2.06	Female	"	?	
10.....	2.15	"	"	Spiders' silk	Female stands on silk and draws out fibres with bill.
11.....	2.19	"	"		Places one foot on silk and pulls out the strands as before.
12.....	2.25	Male and female	"	None	Male pecks at mate, which has brought nothing, as if to urge her to work.

The period illustrated in table VIII witnessed the first successful attempts at molding, and the laying of the first strands to fill the gap at the one open side, thus completing the wall of the cup. At 10.26 a strip of shredded grape vine bark was brought and placed against the nest-mass; then straddling the structure she laid this across the open side, and by means of spiders' silk and many rapid shuttle-movements of the bill, fixed first one end and then the other, springing it slightly in the act. Another strip was laid and secured in the same manner, with an ineffective trial at molding, and then another, when the attempt to mold was successful, in the sense that the bird for the first time maintained her position.

TABLE VIII

Illustrating Building Activity of Red-Eyed Vireo. Second Day (May 31)

No. of visit	Time of visit	Birds at nest	Birds at work	Material used	Remarks
1.....	10.08 a. m.	Female	Female	Floss silk	Works 2 minutes; tries to mold.
2.....	10.15	"	"	"	Tries to mold.
3.....	10.19	"	"	—	Brings nothing; works ¼ second.
4.....	10.26	"	"	Strip of bark	Lays bark across open side, and fastens either end with silk.
5.....	10.28	"	"	Bark strip	Repeats operation and tries to mold.
6.....	10.30	"	"	Long bark strip	Secured as before; works 1. minute; attempts to mold
7.....	10.37	Male and female	"	Spiders' silk	Engaged 2½ minutes; first effective molding movements observed.
8.....	10.39½	Male	None	None	Inspects, but does not enter nest.
9.....	10.42	Female	Female	Silk	Works ½ minute.
10.....	10.52	"	"	"	

At 4 P. M. on the second day the frame of this nest was complete and was composed almost wholly of fine strippings of grapevine bark worked with spiders' silk. The latter was mainly derived from the egg-cocoons of such species as nest on the under sides of leaves or against the clapboards of houses. In certain species the outer layer of the cocoon furnishes an easily worked floss; in others it is snow white and so soft and fine as to be readily drawn into long and exceedingly delicate threads

in places where the paper or yellow birch is unknown this admirable material often forms the sole garnish or fixative for the outer surface. Again even where such substances abound they may be entirely neglected, and the outer surface of the cup left very loose and rough.

There was usually a long pause at about noon when for an hour or more nothing was accomplished, but at other working times their visits would occur every two or three minutes. Towards the close of this day and even earlier, many long strips of bark were hanging free from the entire outer surface of the nest, a condition most noticeable in the oriole (compare fig. 21), and a very characteristic act at this period was either to stand on the twig and bend low, or to cling to it with head hanging down, and quickly picking up one strand at a time, work them with bill into the nest-wall.

The third day at this nest opened with threatening weather, and according to Mrs. Ruedy, who watched the building, work was not resumed with any regularity until about 9 A. M., when bark and silk were still being laid. When we were able to visit this nest again at 3 P. M. the female was quietly sitting in what was now a very serviceable structure, occasionally picking at its rim and outer surface, and adjusting or firming it a bit here and there. In reality the work of construction lasted nearly five days, but from the close of the third day until the end of the fifth the more active labor gradually slowed down, when the female would sit in her egg-cup for longer and longer intervals, until on the sixth day from the start she remained to lay her first egg, after 7.30 o'clock in the morning.

At such times of entering the nest referred to above, and before the appearance of eggs, the bird would sit deep, and repeatedly mold, turn and mold again, scratching with feet, and shaking all over with the violence of her effort; then she would often rise, and dropping her head inspect the inside of the cup, or spend much time in fussing with threads and fixing strips of bark; then more molding movements would follow with perhaps inflation of the throat, and erection of feathers of head and neck, and a cocking of the head from side to side as she peered eagerly about.

The second egg was deposited on the morning of the following day, and also before 7.30 A. M. On the morning of this day the female sat over the eggs for three-quarters of an hour, but then retired and was not seen at the nest again until the following day. After the third egg was laid in the morning of June 6, the female was at the nest almost constantly, and incubation was regularly established. On this day one of the eggs was seen to be nicked, and the next day it had disappeared, presumably removed by the bird. In respect to such conduct there is great difference in individuals. As nearly as could be ascertained incubation lasted 16 days.

Building of the Oriole's Nest.—The Baltimore oriole (*Icterus baltimore*) is undoubtedly our greatest nest-builder; it is a " weaver " of one of the most secure and durable nests known, and so intricate is the product of its "loom," it is perhaps not to be wondered at that remarkable feats of engineering skill have been attributed to it, especially by popular writers. I was naturally on the lookout for any marked exhibition of intelligence above the usual plane of association, but in this respect was disappointed. The oriole works throughout as if stirred by the same kind of impulses which spur a robin or a vireo to their peculiar tasks. There is a method of working characteristic of each, and upon the whole there is the same type of behavior repeated for the hundredth or the thousandth time, with slight variations, as in the many instances already recorded. If my account seem tedious, some allowance must be made for this fact.

The observations which follow give a fairly complete history of the construction of a single nest which was strung at a height of 20 feet, to the pendent spray of an elm on a frequented street in Cleveland Heights Village, Ohio. These notes are illustrated by four sketches (figs. 19-22) made on the spot, and revised by comparisons with the completed nest which was taken down after the birds were through with it. Such drawings are necessarily diagrammatic, and serve only to record general impressions. When first observed at 6.10 P. M., May 14, a few gray bast fibers had been wound to one twig only, number I in figure 19.[41] A year later I saw a female oriole laying her first threads in the same tree and in a similar position, but this time in a high wind which whipped out the strands to a great length and seemed to hamper her to such an extent that the site was quickly abandoned in favor of another across the way.

---

[41] It may be that the primary point of support was on the twig to the right, (No. ii) but this does not matter for purposes of description,only it should be noted that if this were the case the other twigs (Nos. iii–vi, fig. 19) were taken up in reverse order. The fact of particular interest was that the final gap of the nest wall to be filled in, as in the case of the vireo, was on the side opposite the primary points of support.

Though constantly guarded and frequently escorted by the male, the female was the sole builder, and as in the case of the vireo, her visits to the site were noted for their frequency and for the small size of the increments added, as well as for the speed and address with which everything was handled and every situation met. So rapidly at times was this work performed, that it was quite impossible to see and record the movements. The oriole shows the tendency of choosing the fork of a twig for the primary points of support to her nest, but unlike the more uniform practise of the vireo, gradually gathers in two or more forks, or makes use of a number of nearly vertical twigs. So far as observed it never uses a horizontal crotch.

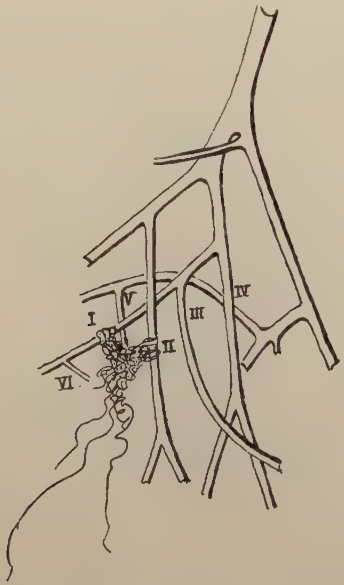

Figure 19. Beginnings of a nest of the Baltimore oriole, showing the two primary points of attachment, and primary nest-mass. Nest begun May 14, at about 4 P. M.; drawing made on May 15 at 7 A. M. Points of suspension, which appear to be taken up in regular succession, and here represented as reading from left to right, indicated by Roman numerals (i-vi). Foliage omitted.

The first strands of bast are wound around the chosen twig rather loosely at first, and often with one or more turns, while the subsequent methods of work tends to draw these threads tighter. Later the fibres appear to be more loosely attached or merely passed over the branch. From this simple beginning a loose pendent mass of fibers is slowly formed, and it is a long time before it takes on the semblance of a nest. As in the vireo, however, this is gradually extended outward, involving twig after twig, until it marks the nest rim, and as slowly growing downward, it represents the first formed part of the nest-wall (figs. 19 and 20). In the case of the oriole there is this difference to be noticed: the primary nest-mass is strictly pendulous, being attached at one or two points, and by a few fibers only, while its free end is frayed into long streamers, some of which often appear to reach a length of 1½ feet.

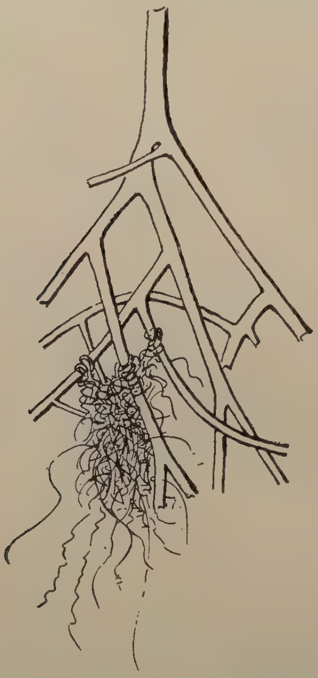

Figure 20. The same nest as it appeared three hours later than the stage represented by Fgure 19. Sketched May 15, 9.45 A. M. Fibres carried to the third point of support, and many long threads hanging free from the nest-mass.

Building operations ceased on the first day at 6.27 P. M., after they had been watched for 17 minutes, and after proceeding for possibly an hour or more. The behavior was essentially the same at each visit, the bird bringing often but a single fiber, carrying it around the support and working it into the nest-mass by what we shall call "shuttle movements" of the bill. Standing upon the twig or clinging to it in any position, and holding the thread, the bird, makes a series of rapid thrust-and-draw movements with the bill. With the thrust the first fiber is pushed through the mass; at a second thrust either that fiber or another is drawn back. Most of the threads brought at a later time are treated in this way, that is, they are worked into the primary nest mass by one end, and left with the other hanging free. But again one end of a strand being fixed in the way described, like a flash the other end is picked up, passed

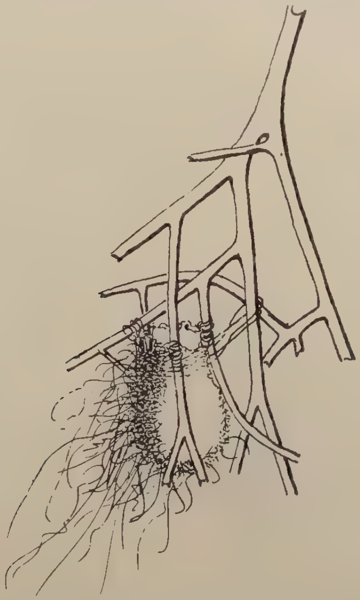

FIGURE 21. The same oriole's nest after about ten hours of constructive work, showing rim formed, and nest-wall blocked out with the exception of one open side. Bottom and upper web between second and third points of attachment very thin; outer wall characterized by long streamers which are later withdrawn and worked into the wall from the inside. Sketch made at 1 P. M., May 15.

over the twig or wound around it and finally secured. While these shuttle movements are, first and last, very similar, and almost equally rapid at all times, the number made at each visit tends to increase as the work progresses in order to treat the greater number of accumulating threads. One hundred shuttle movements or thrusts are sometimes made in the course of a single visit, and the motion is frequently too rapid to be followed.

In all this admirable work there is no deliberate tying of knots, yet as we shall later see knots in plenty are being tied all the time; there is no deliberate pulling of the threads, as when a hammock is carefully woven by hand; the work is all fairly loose, yet some threads get drawn tighter than others. Note further that we do not say that the thread which is thrust through is always drawn back at the next move, only that something is redrawn. The irregularity of the weave of the finished work shows conclusively that the misses are as frequent as the hits in this respect. The last remark does not

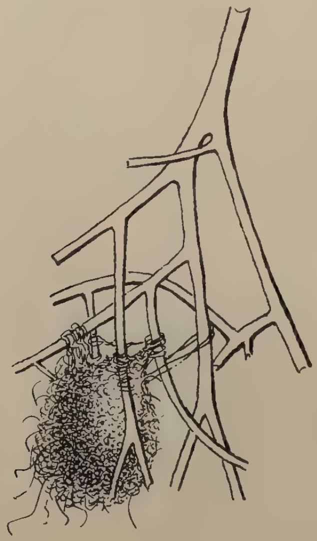

FIGURE 22. The nest of the oriole on the third day after about 20 hours of work; May 16, 7.30 A. M. The nest is completely outlined, but the wall opposite the first completed side is still thin; the outer free fibres have been mostly drawn in and woven into the pouch. Nest secured at six points, the fourth (iv, fig. 19) showing four or five strands only in completed nest. Entire working period of female about 4½ days.

apply to the passage of a strand around a twig, when the head and neck are turned and twisted in such a way that mistakes are needless.

What was the result at the end of approximately two hours' working on the first day? Simply this: a small mass of bast had been firmly secured to a primary supporting twig, with a few hairs or fine strands visible only by aid of a glass uniting it to a second support, the body of it knotted and interlooped at no doubt hundreds of points, with long strands hanging free at unsecured ends (compare fig. 19).

While at work the oriole frequently spreads wings and tail as an aid in balancing, and when a stiff breeze is blowing there would seem to be no position or acrobatic feat which such a bird cannot assume or perform. The oriole's peculiar harsh chatter, which is clearly not always a source of alarm, was often heard from this working bird, while the male sang jubilantly from a station near at hand.

On the second day the work of construction was under way as early as 5.15 A. M., and at 7 o'clock the primary nest-mass had the appearance shown in figure 19. It should be added that the actual number of fibers composing this body, is much greater than could either be seen, or shown in a drawing, but the only progress visible to the eye at a distance of 20 feet was registered in the greater number of fibers leading from the second point of attachment, and in the denser character of the mass itself. With every visit most attention was always devoted to the swaying mass, yet as before it had the appearance of being knit with very loose stitches; nothing seemed to be drawn tight with the possible exception of some of the fibers binding the twigs. The records given in Table IX embrace a period of continuous observation with the exception of two breaks between numbers 9 and 10, and 15 and 16. The time spent in working at successive visits varied from 10 seconds to 3 minutes, and the material used consisted almost wholly of gray bast in its natural form or shredded into strips of a few inches to over a foot in length, all procured from an adjoining swampy tract and a few other points in the neighborhood. Rarely more than a single fiber was brought at a time, and as already noted the attention which this received was only a fraction of that bestowed on the nest-mass.

TABLE IX

BUILDING RECORDS OF THE BALTIMORE ORIOLE. SECOND DAY (MAY 15)

No. of visit	Time of visit	Bird at nest	Materials	Time at nest	Remarks
	a. m.				
1.....	7.05	Female			Nest secured at two points
2.....	7.07	"			
3.....	7.12	"	Bast	½ minute	Gives alarm on alighting and male drives house sparrows.
4.....	7.13½	"		¼ minute	
5.....	7.16	"		10 seconds	Gives alarm again.
6.....	7.20	"	Several long bast strands	2 minutes	Sings while working.
7.....	7.30	"	"		" "
8.....	7.34	"		3 minutes	Sings and makes 100 shuttle movements
9.....	7.37	"			Sings while at work.
10.....	7.58	"		3 minutes	
11.....	8.02	"		3 minutes	Leaves with alarm.
12.....	8.05	"		1½ minutes	" "
13.....	8.08	"		3 minutes	
14.....	8.16	"	Bast	1 minute	
15.....	8.19	"		2 minutes	Nest secured at 3 points.
16.....	9.45	"			
17.....	9.52	"		¼ minute	
18.....	10.02	"	Bast strip		Gives alarm

During the forenoon of the second day the female worked with the same rapidity and decision, pushing her threads with a dart of the bill through the nest body, catching up their ends or the ends of some other strands and drawing them through in the opposite direction, with one foot often grasping a twig and with the other the nest-mass, thrusting and pulling, now straddling the mass and balancing with spread wings, working at it from above, from below, or at either side, always at each visit not only working on the strand placed, but on many others which were hanging free. The result shortly after 8 o'clock showed a web of interlaced fibers attached to three twigs, representing about one-half the margin of the future nest, and extended downward and laterally into a loose fabric which one hour later had the appearance shown in figure 20.

By the end of the period represented in Table IX two additional twigs had been included, thus virtually completing the rim, and the free mass was coming to take on the curved form of the nest wall. Further it was worked almost wholly from what we may now call the inside. At 11.35 A. M. on this day the nest rim, though incomplete was more pronounced, but no proper bottom to the nest could be discerned. Up to this point nothing suggestive of molding movements had been noticed. At the next visit, two minutes later, the oriole brought several bast strips held crosswise in bill according to her wont, and quickly worked them in; then catching up the free end of a long thread she carried it around a twig a little farther away and endeavored to secure it; this represents either what we have designated as the fourth point of attachment (compare fig. 19, iv, and fig. 21), or an abortive attempt to use some other point still farther away. The fourth supporting twig in the complete nest carries only four or five strands.

At 1 o'clock P. M. (see fig. 21) the nest was outlined in full, but with one side open with the exception of a thin web at the top. This gap (not quite correctly shown in the drawing) is nearly opposite the original free mass, which has now become the thickest part of the nest wall. The most striking character of the nest at this stage are the long free fibers, which hang down from all sides of what represents the outer surface. They are for the most part worked into the bottom and side walls and are invariably drawn through from the inside with rapid strokes of the bill. At 4.15 P. M. the upper thin web between the second and third points of supports had perceptibly thickened and grown downward, while a lower web was extending upward from the bottom.

At 7.30 A. M. on the third day, after from 15 to 20 hours of constructive work, the nest had the appearance roughly shown in figure 22. There still appeared to be a gap opposite the first finished side (shaded light in the drawing), but with a glass it could be seen that this space between the upper and lower webs referred to above was transversed by a framework of fine fibers. Further the long loose threads had been mostly drawn in, and at this period the bird or rather her "shadow" was working busily at the task from the inside of the pouch, and the point of her bill with sometimes a part of the head could be seen piercing the loose wall in the characteristic shuttle movements to which we have often referred. The first molds were noticed while the bird was thus partially screened from view as was indicated by a vibration of her wings and shaking of the whole body, and although the successive turnings could not be detected they undoubtedly occurred. By noon of this day the last part of the wall to be filled in looked thin enough to easily admit a lead pencil or a finger, but at its close (6.45 P. M.), this could not be said; the shagginess of the outer walls had mostly disappeared; the bottom was thicker and the walls nearly uniform throughout. The male was not seen, and high winds had hampered the builder throughout the day.

Work at this nest slowed down very perceptibly on the fourth day (May 17), when the builder was almost completely concealed within her pouch. So far as could be ascertained it consisted of adding further lining substances and stitching them in, drawing in more of the outer loose threads and in general completing the symmetry of the pouch. By five o'clock all was quiet at the nest, and neither bird was seen after this time. Activity on the fifth day was still slighter, and was devoted to additions to the lining, to molding and readjustment The period of constructive work in this instance was thus about 4½ days.

Materials of the Oriole's Nest.—I have seen an oriole's nest made largely of scarlet yarn, and another was found by one of the pupils in the Cleveland schools worked entirely with horse hair. Yet they use with great uniformity the dead leaves of certain grasses and the bleached fibrous tissues of various herbaceous plants, as well as bark strips and hair. Wherever the cotton grass abounds its white fluffy heads are apt to be sewed into the bottom as lining. According to Audubon[42] the Baltimore oriole in Louisiana builds entirely of Spanish moss, without the use of "warming" substances of any kind. His brief description of the building of the nest, implying as he does that the whole is outlined with the laying of the first threads which are made to "cross and recross so as to form an irregular network," is surely at fault.

Suspension of the Oriole's Nest.—The method of suspension is similar in all the nests of this species examined; a variable number of fibers are passed over or around the primary and secondary supports. I have seen a long piece of cotton twine looped ten times around the main twig and secured at either end into the nest wall.

---

[42] Op. cit. vol. 1, p. 68.

The nest, the building of which has been described, was attached as we have seen at six points, beginning with the first two, shown in figure 19, and passing from left to right until eventually the rim was enclosed; the sixth twig being a subordinate branch of the first and lying below the level of the primary supports, does not enter into the rim, but is worked into the wall, lower down. All told these six twigs bear about 200 slender strands of bast; some are simply passed over the support with several inches clear and worked into the nest at either end (as in iv), while many are wound closely about the twigs and both interwoven and knotted in the thinner web of the rim. As to their strength we found that they could easily sustain a weight of eight pounds. The strength of the wall itself is best seen by attempting to break through it or tear it apart. It is probably no exaggeration to say that the walls of some of these nests contain 10,000 stitches and thousands of knots and loops. If we allow 40 working hours and but five visits to the hour, I think 20,000 "shuttle movements," pushing a thread through and drawing it or some other thread back, would be a moderate estimate of one phase of the activity of an oriole in weaving its nest.

The oriole's stitches bear as little relation to the deliberate work of the tailor in first knotting his thread and then sewing his garment, as the molding and turning movements of a robin bear to the hand work of a potter. The oriole can and does tie as good a knot as tailor or sailor, and the robin may "turn" as true a cup as that thrown on a potter's wheel. The results are indeed similar, but the impelling impulses widely different. In the case of the birds the results are so clearly due to a stereotyped form of behavior determined by heredity in all essential respects, that any discussion of intelligence involved much above the plane of association is superfluous. Considering the rapidity and persistence of the shuttle movements, is it any wonder that the knotting and interlooping of the threads presents an irregularity and complexity which baffles description?

Nest Building in Other Species.—To describe in detail the building habits of Chebecs (*Empidonax minimus*), bluebirds (*Sialia sialis*), and chipping sparrows (*Spizella socialis*) would involve much repetition, and we can refer to a few only of the most interesting facts observed.

Chebecs.—A pair of chebecs took a great quantity of the white yarn and shredded white cloth which was offered them and built an extraordinary nest. In its completed state it resembled a great white tassel, for not only was it conspicuous, but a trail of streamers led from field to tree. The nests of this species are both neatly molded within and smoothed without, and although many times the quantity of material needed was used in this instance, the smoothing process was attempted and in a peculiar manner. Standing in the cup of the nest and bending down, the chebec drew alternatingly right and left side of head and neck in one continuous movement over its outer surface as one would strop a razor; turning and repeating the movement the outer wall was thus "ironed" over and over again. From one to two minutes were commonly spent in the molding and smoothing processes.

Chipping Sparrows.—The chipping sparrow, as already noticed, builds a fragile and insecure nest, but molds a perfect cup, which is often composed entirely of hair. The molding and turning movements are practiced with great persistence and resemble those of other species studied. The behavior of the pair, from the time when the nest is nearly ready until incubation begins, has been watched in a number of cases, and it suggests the chain-like character of all their instincts. After molding, the female would drop to the ground, and with wings spread and a-quiver, twittering the while, she would await the approach of the male. Copulation was always performed by the male when on the wing, and quickly repeated; thereafter the female would at once repair to her completed nest, sit in it for a few minutes and then fly off. In the course of over two hours these actions were repeated four times, and again at eight o'clock of the following day they recurred, the female always going promptly to her nest and remaining in it for about three minutes. At such times she would occasionally make a few molds, but was never seen to add anything to the structure. Behavior of this character was continued until the appearance of the first egg which was laid before 4.50 A. M. After leaving the nest the female dropped to the ground, quivering and twittering as before, but there was no approach of the male, although the pair was presently seen foraging for food. After laying her second egg this bird came off her nest at 4.56 A. M., dropped down quietly and was joined by the male in her search after food. Incubation, as in other instances noted, began with gradually lengthening periods of sitting until the appearance of the third egg, when it was regularly established.

Bluebirds.—While watching bluebirds carrying nest materials to a box, 47 visits were made by one or both birds in the course of 70 minutes, or with an average of one visit every 1½ minutes. Male and female were at the nest box together 22 times during the interval, and the male made two visits alone. The usual proceedings at these functions were as follows: The female leading but closely followed by the male, flew to the top of the box with her load of straws or dead grass held crosswise in bill, entered and spent from a few seconds to a minute inside, peered out and was off; the male, atop the box, would warble while his mate was at work inside. Now and again he would look into the hole or even enter and when the female left he followed her quickly away. At other times he would drop and shake his wings, warbling all the while, as an invitation to the copulatory act, and would pursue his mate, if she were coy. Once only was the male seen to bring a straw, and this caught at the entrance and was dropped, but more than once he entered the box and carried a straw away. Once he awaited a full minute inside, and until his mate returned with a fresh load.

Twice the male bluebird brought an insect to the nest-box, but it was not destined for his mate, and on one of these occasions he clung to the entrance, like a bird bringing food to its young, flying to and fro with it, shifting it about and finally swallowing it himself. His chief office in the building process was evidently that of guardian, but some of his acts which have just been described suggest an imperfect development of the building instinct, as well as a premature rise of the instinct to feed the young. This bringing of food to the nest while the work of construction is still under way seems to be perfectly paralleled by the behavior of the male robin already described (see p. 346).

Woodpeckers, Chickadees, Kingfishers and Swallows.—Among birds which excavate in wood the flicker and the red-headed woodpecker are typical, working solely with their powerful bills, which are used as picks. We cannot describe the process of excavation in detail, but wish to point out the following facts: The gourd-shaped chamber which results is as typical in form and measurements as the clay cup of a robin or the elastic pouch of an oriole. The diameter of the entrance is highly uniform for the species, and often as truly circular as if cut with an auger. Both sexes work, and the time of building which may extend over a week, depends in a measure only upon the hardness of the wood. According to Audubon the ivory bill regularly chooses a living tree, and I have seen a spruce telephone pole successfully worked by the red-head. Like so many other species, the flicker will occasionally adapt natural cavities, and has been known to nest in the sawdust of an ice house or even to burrow in a haystack. The same flicker's hole may be used for a second brood, or by the same or other birds for a series of years. That holes are used as winter quarters is not to be doubted, but if such are dug out for this purpose the fact is interesting, though not without analogies in other species. Moreover, if a breeding pair be disturbed they will sometimes abandon their hole and excavate another, but this does not always follow; the same hole may be taken and deepened [43] Compare such conduct with that of a vireo (see p. 258. Part ii), which abandons a new nest with or without eggs through fear, but uses it as the *site* for building a new one, the result giving us a compound or superimposed nest, in the lower section of which a cowbird's egg may be concealed.

The chickadee which not only adapts a natural hole but digs with great labor an artificial one, flies away with every chip removed and drops it at a distance, male and female working in alternation. The red-bellied nuthatch like the chickadee will use a natural cavity or dig one in wood, in which case it is careful to collect drops of freshly exuded pitch and smear them about the entrance. The effect of this is supposed to discourage intruders, but this appears doubtful; it may represent the echo of an instinct to narrow the opening as seen in the European nuthatch already noticed, and suggests the behavior of the tropical hornbills (see p. 170, Part ii).

The building habits of the belted kingfisher (*Ceryle alcyon*) and the bank swallow (*Clivicola riparia*) are similar to this extent that both use the bill as pick, and scratch out the detached earth with their feet. Both drive a straight or inclined tunnel of fairly uniform dimensions, and excavate an arched chamber at the end, although unlike the martin the kingfisher carries in no nesting materials, the fish bones or crayfish shells which are found in its chambers representing the disgorged remnants of its food.

---

[43] See Audubon; Op. cit. vol. ii, p. 75. Edinburgh, 1834.

The nesting habits of the American eaves swallow (*Petrochelidon lunifrons*) and the European house martin (*Chelidon urbica*) appear to be similar in essential respects. In the former a retort-shaped shell of clay or mud is glued to the steep sides of rocky cliffs or under the eaves of buildings, a short symmetrical entrance tube being built out opposite the side of attachment. The "retort" has a beaded appearance over its entire surface, being composed almost wholly of rounded pellets laid one at a time, when moist, and presumably mixed with a certain amount of saliva, the chamber thus formed being eventually lined with grass and feathers. According to Gilbert White[44] the English house martins fix the pellets of which their nest is similarly composed by the aid of their chins, "moving their heads with a quick vibratory motion." Usually building to a northeast or northwest aspect, they are at work before four o'clock in the morning, but as White remarks in another place, "that this work may not, while it is soft and green, pull itself down by its own weight, the provident architect has prudence and forbearance enough not to advance her work too fast; but by building only in the morning, and by dedicating the rest of the day to food and amusement, gives it time to dry and harden. About half an inch seems to be a sufficient layer for a day." From 10 to 12 days are usually occupied in building this mud nest.

The South American oven bird (*Funarius*) in rearing its arched chamber of mud, dung, and grass, is said to pause frequently in the work in order, as we are told, that its mortar may set and harden before proceeding to spring the arch and mold the roof. I have noticed that some of the mud-daubing wasps do not work continuously at their clay-tubes, which thus stiffen to some extent before they are completed, and we do not consider such behavior in bird or insect as indicative of intelligence. As to the "prudence" of the house martin we should compare the contrary notice of its stupidity mentioned earlier (see Part II, p. 255).

---

[44] Ibid. p. 134.

Cooperation in Nest-Building.—In the building of a nest to be used by a single pair of birds, the work may be performed by one or both sexes, though commonly devolving upon the female alone. So far as I have observed, when both sexes cooperate effectively, they act alone, and usually in silence. The occasional bringing of materials by the male, as in the case of the red-eyed vireo, as noticed above, to be immediately taken and used by his more active mate, may be compared to the bringing of food by the cock after the young are hatched, and its prompt service by the hen, a fact which we have recorded in a number of species. That swallows or any other birds which are gregarious during the nesting period cooperate in such a degree that several adults unite in the effort of building a single nest for the use of a single pair, as has been reported by various writers, is undoubtedly an error.

7. INTELLIGENCE IN NEST BUILDING

There is no doubt either that instinct furnishes the springs of action in birds, or that their instincts are extremely complex and in a high degree adaptive. Nor is it to be further questioned that this innate equipment takes the place in large measure of mind or intelligence. We have used the latter term in the sense of the power of learning by individual experience, or of forming habits, by which we designate fixed ways of action, not innate. We know that by the aid of intelligence an animal can lead a fuller and more successful life, and we assume that in some unknown way its more variable intelligent responses have arisen from its more uniform instincts.

Do birds display exceptional intelligence in building their nests? The answer is No, but if the impression has been conveyed that at this time birds are more the slaves of instinct than at any other, it is probably erroneous. No time or period is favored in this respect, except to the extent that the keener the impulses to action, the more uniform the conduct. In nest-building instinct boldly outlines behavior, and may indeed be responsible for many of its complex details, while certain shadings and variants of no mean import, are as surely the result of individual acquisition, due at least to the association of motor impulses with sense impressions. There is further, evidence that birds adapt means to ends or do things to effect changes which they seem to desire to bring about. In other words at times they seem to strive with an end in view, and continue to work until their aim is achieved. Whether such acts as we now refer to are really attended by an association of ideas, or merely result from the gradual elimination of useless movements after successive trials, we cannot say.

Habits, it is true, are likely to arise at every step, and we have already seen how quickly birds acquire a certain way of approaching and leaving their nest-sites. That the method of dealing with the nest material is remarkably uniform has been suggested from the analysis of the structure of nests already given. Such facts, not to speak of the aberrations and eccentricities already accounted for, speak loudly for the cardinal rôle of instinct in all nest-building operations. As to adapting means to ends we might refer to the behavior of robins in their use and treatment of strings when difficulty arises (see p. 348). Compare also the behavior of bluebirds, house martins and wrens in their efforts to carry into their nest-boxes, straws and twigs, which are too long for the hole. When such a bird is brought up at a short turn at the entrance, it usually tries to force a passage, and upon failure repeats the attempt until it either succeeds or drops the object. Like the dog trying to carry a stick through a hole in a fence, the object is bound to be shifted back and forth in the mouth, until held in a certain position, when it is able to push it through. It seems probable that in the case of the bird the right shift of the bill to one end might in a certain proportion of cases quickly lead to the formation of a useful habit. According to a writer in Bird-Lore,[45] this appears to have been the case with a pair of house wrens, both of which learned the trick of slipping the bill to one end of the twigs, and thus pushing them into the opening. The male was an adept at this and his mate though unskilled at first soon acquired the habit, and "it was not long before, upon bringing a twig to her door, she would deliberately begin to move her bill to one end or the other."

---

[45] Thoms, Craig S., Must Wrens be Taught Nest-Building. Bird-Lore, vol. xii, p. 181. New York, 1910.

8. ORIGIN OF THE INSTINCTS OF INCUBATION AND NIDIFICATION IN BIRDS

In an earlier work we endeavored to show that the instinct to hide supplemented by that of guarding the eggs was responsible for the later instinct of incubation, where guarding with concealment is effected in the same act.[46]

We have seen how the protection necessary to eggs, young and adults has been secured, and how a proper nest may contribute to this end. Incubation, arising in its initial stages through the instinct to guard, and to conceal by covering with the body, and later perpetuated and established, as we may infer, by selection, in all probability long antedated any effective nest-building.

The most primitive nests undoubtedly belonged to what we have called the "secondary adaptive" type, mere holes in the ground or in trees. Increment nests may have arisen in the first instance through an earlier practise of collecting materials of any description to cover the eggs upon leaving them to look for food. All such would be scattered to some extent upon re-entering the nest to cover and guard; some, however, would remain to form a rude rampart or wall of circular form, and this would be advantageous in holding the eggs to a focal point. By the slight advantages thus gained, supplemented it may be, by a practice of drawing materials towards the body while incubating, suggested by the present day actions of certain gulls and terns, may have furnished a starting point for the increment nest of the statant type.

The exceptionally interesting breeding habits of the nutmeg or Torres Straits pigeon (*Myristicivora spilorrhoa*), as described by Banfield[47] at Dunk Island, Australia, offer further suggestions upon this subject. This pigeon, we are told, breeds on the island during a period of four months, from the end of September to the end of January, rearing two or three young, one at a time, and that "for each successive egg a carpet of twigs or leaves is spread." Those pigeons which "incubate on the ground discard even the rude platform of twigs, which generally represents the nest of those which prefer bushes and trees, but gradually encircle themselves with tiny mounds of ejected seeds, until the appearance of a nest is presented. At the termination of the breeding season these birthplaces of the young are indicated by circular ramparts, in the composition of which the aromatic nutmeg predominates." Now the fact that birds commonly acquire a fixed habit of facing one way while sitting over the eggs or young suggests that this "building" of an enclosing wall may not be wholly casual or insignificant.

---

[46] Home Life of Wild Birds, p. 146.

[47] Banfield, E. T. The Confessions of a Beachcomber. New York, 1909.

NOTES ON THE BEHAVIOR OF A PARASITIC BEE OF THE FAMILY STELIDAE

C. H. TURNER

Sumner High School, St. Louis, Mo.

So far as my knowledge goes, nothing has been published upon either the habits or the behavior of the American Stelidae; therefore, it is thought that the following notes, although fragmentary, will prove of interest to students of animal behavior.

In the early part of May, 1911, I received, from Mr. Phil Rau of St. Louis, a few mud cells containing thirteen imago bees of the family Stelidae, about a third of which were females. The cells in which these bees were found were those of one of the mason wasps (*Pelopaeus sp.* ?). That these bees spent their pupal life in those cells is a certainty, for they emerged from their pupal cases while in the possession of Mr. Rau. Since the food of bees is so unlike that of wasps, it does not seem probable that these bees are parasites of the mason wasp; therefore, it seems safe to presume that this mud-dauber's nests had been appropriated by some non-parasitic species of solitary bee, and that a female bee of the family Stelidae came along and, by depositing her eggs upon the food intended for the young of her host, initiated a tragedy.

As soon as received by me, the mud cells containing the bees were placed on the floor of an insect cage sixteen inches high, twelve inches wide and twelve inches deep. The bottom and framework of this cage were constructed of wood, the sides and top were covered with fine wire gauze. When not under observation, the cage containing the bees was kept in an ordinary school-room, with an average temperature of 70 degrees by day and a minimum of 60 degrees by night. On nights when there was danger of the temperature falling below sixty, the cage was placed in a conservatory, where the temperature was between 70 and 80 degrees.

These mud cells from which the insects were hatched were to them a real home. At night or whenever the room was darkened or when the atmosphere became a little cool, these bees would retire to the mud cells and rest therein. The method by which they found the way back to the mud cell was not determined experimentally, partly because the habit was established before I received the bees and partly because the size of the cage was thought too small for satisfactory experiments of that kind.

FEEDING HABITS

The bees were fed on honey deposited either on glazed paper or in Minot watch glasses and placed on the floor of the cage. When the honey was first placed in the cage, there was no special rushing for the food nor were any special hunting movements initiated by its presence; but, when a bee, either male or female, chanced to come in contact with the honey, it would stop and feed. On the paper, I always dropped a very small amount of honey; in the watch glass, I poured enough to cover about one-half of the bottom. An attempt was made to always place the honey in the center of the watch glass. To feed from the small drop of honey on the paper never caused the bees any trouble; but the larger amount of honey in the watch glass was, at first, a source of much inconvenience. It was amusing to watch a bee feeding from it. While feeding the bee was certain to get one of its feet into the honey. In striving to extricate the leg, the bee would invariably get another foot smeared. This would serve to complicate matters. Sometimes the bee would succeed in backing out, but more often it would wade through the honey to the opposite side of the watch glass. Then it would drag itself along to some good resting place and attempt to clean its besmeared body. After a few days, it was noticed that the bees fed from the honey in the watch glass without getting into it; but the number of observations were too few to warrant the assertion that they had profited from experience. This inability to give a definite answer to this question is not due to a failure to attempt to secure evidence, but to the fact that the bees fed only occasionally and at uncertain intervals.

After sipping honey for a short while, unless too much smeared with honey to fly, the bee would ascend on its wings, to about an inch, or a little less, above the surface of the honey and describe several horizontal circles, the diameters of which were gradually increasing in length. After this short flight of orientation, the bee would fly away; sometimes to the sunny patch on that wall of the cage through which the direct rays of the sun were entering (Ex. 13), sometimes to a shady place, and sometimes to one of the mud cells. On reaching the mud cell, it might either pass inside or else rest on the outside and clean itself (Ex. 23). Indeed, as the following example shows, the same bee, on successive trips to the honey, often behaved in different ways. A bee had been sipping honey from a dish situated in the shade. After making a short flight of orientation, the bee flew towards the left and alighted, in the sunshine, on that wall of the cage. After resting a few minutes, it flew again to the honey. From the honey, it returned to the sunny patch on the left side of the cage. After resting momentarily, it flew again to the honey and from the honey to a sunny patch on the wall of the window-side of the cage. (This wall made an angle of ninety degrees with the left wall of the cage.) From this window-wall the bee flew into a mud cell which was situated in the shade. The flight of orientation mentioned above was performed whether the honey was situated in the sunlight or in the shadow. It is now well known, to all students of animal behavior, that the non-parasitic wasps and bees, whenever leaving, for the first time, anything which it is to their interest to re-visit, always make a short flight of orientation. The Peckhams, the present writer and others have interpreted this flight of orientation as a device for furnishing memory pictures of the environment for the future guidance of the creatures. It is interesting to note that these parasitic bees have this same habit; for it indicates that they, too, have memory.

One could not help being struck with the extreme tameness of these parasitic bees. Without any preliminary training, the bees would rest quietly on my finger and sip honey, either from another finger or from the back of the finger nail of the same finger. If I gently moved my finger along the floor of the cage, or along any other support, until the tip of my finger was gently touching the anterior end of a bee, that bee would usually mount the finger. On gently moving the finger until the mouth of the bee was within a millimeter or two of honey placed on the tip of one of the fingers of the other hand, the bee would immediately begin to sip the honey. If a bee were resting on the finger in such a position that its head was directed towards and near to the finger nail, a drop of honey placed on that nail would cause the bee to begin to feed. On one occasion, I carried a bee that was thus perched upon my finger a part of the way around the room and back to the cage without disturbing its feeding movements. The bees reacted towards my fingers just as they would have towards sticks or other inanimate objects. This result was not altogether unexpected; for, several years ago, I had a somewhat similar experience with the South Carolina yellow-jacket (*Vespa carolina*). These wasps had been raised in the laboratory, from eggs and pupae collected from a wild nest. From the beginning of their imago life, the yellow jackets had been trained to feed on honey placed upon the tip of one of my fingers. After a week had elapsed, whenever I presented my finger to any one of the large so-called queens she would mount that finger and rest quietly thereon. With the tremulous wasp thus perched upon my finger, I could move from one room to the next and back without the yellow-jacket either taking flight or making an attempt to sting. In the case of those *Vespas* the preliminary feeding with honey placed on the finger tips may have been a kind of training for the other behavior; but in the case of the parasitic bees described above there had been no preliminary training of any kind.

MATING HABITS

While conducting a series of experiments on the reactions of these bees towards light, I had several opportunities to study carefully the method of copulation. In each of the cases observed the method was essentially as follows: While the female was resting in the sunlight, upon the netting of that side of the cage through which the direct rays of the sun were entering, the male mounted her back. Grasping the female with its front two pairs of legs, the male curved its abdomen slightly until, with jerky movements, it had succeeded in bringing the genitalia into good contact. Throughout practically the whole period of copulation, which lasted about five minutes, the male patted the sides of the abdomen of the female with his hind legs. In each of the cases observed by me, the female lost her grip on the netting and the pair dropped to the floor of the cage. The male, however, retained his position upon her back. In one of the cases the female remained where she fell until the male departed; in the other cases the female roamed about with the male on her back. In one case she even partly reclimbed the wire netting.

In each case that I had the opportunity to watch from the beginning to the end, the first stages in the act of copulation always occurred in the direct sunlight. This might lead one to think that, in nature, copulation always begins in the direct sunlight; but, such a conclusion would be erroneous. On one occasion I found a pair in copulo, on the floor, with one half of each body in the sunlight and the other half in the shadow. At the same time, on another portion of the floor of the same cage, I discovered a pair in copulo in the shade. On yet another occasion, on the netting of one of the walls of a cage that had been in diffuse daylight for several hours, I found a pair of these bees in copulo. When that cage was placed in the room none of the bees was mating. Since it was impossible for the direct rays of the sun to reach the cage, we have here conclusive proof that copulation may be begun and carried to completion in diffuse daylight.

DESCRIPTION OF EXPERIMENTS ON THE INFLUENCE OF LIGHT

SERIES I (MAY 2, 1911)

EXPERIMENT 1.—*The cage was so arranged, in a window, that the side towards the window, the side opposite the window, the top and the bottom were in the sunlight. On the bottom of the cage and on the side opposite the window were narrow bands of shadow caused by the framework of the cage.*

In a few minutes five bees flew towards the window-side of the cage and alighted thereon; one of these rested four inches from the top of the netting and the other four near the bottom.

EXPERIMENT 2.—*At* 8.45 *a. m., the above cage was rotated, as gently as possible, through an angle of* 180 *degrees. This caused the bees that had been resting in the sun on the window side of the cage to be transferred to the side that was most remote from the window.*

Immediately three of the bees left the sunny place on the side of the cage most remote from the window and flew towards the window-side of the cage and rested thereon, in the sunlight. In a few seconds these three bees were joined by another bee that came out of one of the mud cells. This gave four bees resting on the netting of that side of the cage through which the direct rays of the sun were entering and one resting, in the sunlight, on the opposite side of the cage.

Experiment 3.—*At 9 a. m., the room was darkened and kept so for forty-five minutes.*

At the close of this period, one bee was resting on the netting of that side of the cage through which the direct sunlight had formerly entered, three were clinging to the netting of the top of the cage and the remainder were on the floor.

Experiment 4.—*At 9.45 a. m., the cage was placed in a window through which the sunlight was entering. The window-side of the cage, the top, the side remote from the window and the floor were in the direct sunlight. The bees clinging to the top of the cage were jarred off.*

At 9.53 A. M., five bees were resting on the netting of the side of the cage through which the direct rays of the sun were entering and one was basking in the sunlight on the floor. No other bees were in sight. The bees on the netting did not rest quietly thereon. They seemed to be quite restless. They would crawl up the netting, through the sunlight, until they reached the border of the dark place at its top, then they would usually drop downwards, nearly to the floor, fly against the netting and repeat. Occasionally, on reaching the shadow, the bee would enter it and crawl about in it a short time before dropping.

At 9.56 A. M., six bees were moving restlessly about on the neting of that side of the cage through which the direct rays of the sun were entering and two were moving about, in the sunlight, on the floor. No other bees were in sight. The bees on the screen behaved in the same manner mentioned above. Sometimes, instead of climbing all of the way, the bee flew upwards for a part of the distance.

At 9.59 A. M., seven bees were moving about on the netting of the side of the cage through which the direct rays of the sun were entering. No other bees were in sight.

Experiment 5.—*At 10.00 a. m. the cage was rotated, as gently as possible, through an angle of 180 degrees, and the lower six* *inches of the netting of the window-side was covered with an opaque screen. This placed the top, the upper four inches of the window-side and the lower portion of the side remote from the window in the sunlight. Except for a narrow band of sunlight on the floor, the remainder of the cage was in shadow.*

At 10.05 A. M., eight bees were in the sunlight; three on the window-side of the cage, four on the top and one on the floor. No other bees were in sight.

At 10.08 A. M., two bees were in the sunlight on the window-side of the cage, three in the sunlight on the top, two in the band of sunlight on the floor and one in the shadow near the upper edge of the window-side of the cage.

EXPERIMENT 6.—*At 10.10 a. m., the opaque screen was removed from the window side of the cage and the bees jarred from the top of the cage. This placed the top of the cage, the window-side, the side remote from the window and a portion of the floor in the sunlight.*

At 10.15 A. M., seven bees were in the sunlight on the window-side of the cage, and one sipping honey, in the sunlight, on the floor. No other bees were in sight.

EXPERIMENT 7.—*At 10.17 a. m., the cage was rotated, as gently as possible, through an angle of 180 degrees.*

At 10.18 A. M., nine bees were in the sunlight; four on the netting of the window-side of the cage, four on the side remote from the window and one on the floor. No other bees were in sight.

At 10.20 A. M., nine bees were in the sunlight; seven on the window-side of the cage, one on the side remote from the window and one on the floor. No other bees were in sight.

At 10.24 A. M., eight bees were in the sunlight; seven on the window-side of the cage and one on the floor.

EXPERIMENT 8.—*At 11.40 a. m., an opaque screen was placed between the window and the cage; this placed the window-side of the cage and the side remote from the window in the shadow. On the top, the right and left sides and the bottom were bands of sunshine and shadow.*

Almost immediately the bees left the window-side of the cage. Some flew towards the light places on the left side, some flew against the sunny patch on the roof of the cage and several climbed up the light place on the left side to the shadow at the border of the top. Several of those that flew up to the top of the cage clung thereto and walked about, sternum upwards, in the sunshine.

Experiment 9.—*At* 11.45 *a. m., an opaque screen covering the upper six inches of the netting of the window-side of the cage was substituted for the opaque screen used in Experiment* 8. *This caused the lower portion of the window-side of the cage to be strongly illuminated, while the upper six inches was in shadow. Otherwise the arrangement of light was as in Experiment* 8.

The day was warm, the temperature in the shade was 88 degrees F., and the bees were restless. They would not remain long in any one position. In this experiment accurate account was kept of the number of times bees alighted, in ten minutes, on any netting of the cage. If the same bee alighted on any of the walls more than once it was counted each time. During that period bees alighted on the light patch fifteen times. Thirteen times a bee climbed up through the sunlight on the window-side of the cage until it reached to edge of the shadow and then dropped backwards. One bee climbed up through the sunlight on the window-side of the cage and continued on into the shadow until it reached the top of the cage, and rested there several minutes. Another bee did practically the same thing, only it stopped before it reached the top.

SERIES II (MAY 3, 1911)

Experiment 10.—*At* 2 *p. m., the cage was placed in front of an electric projecting lantern and a beam of light allowed to pass through. On the lantern-side of the cage the beam of light was eight inches wide by six inches high; on the side remote from the lantern the beam was nine by seven inches. On the lantern-side the bottom of the beam was four inches above the bottom of the wire netting, on the opposite side of the cage the bottom of the beam of light was two and a half inches above the bottom of the netting. The other portions of the cage were illuminated by diffuse daylight, admitted by windows on one side of the room.*

At the beginning of this experiment a few bees were resting on the netting on the window-side of the cage, the remainder were out of sight. As soon as the light was turned on, a male bee crawled up from the shaded portion into the brightly illuminated patch on the lantern-side of the cage, roamed about for a short time and then rested quietly thereon. At 2.08 P. M., another bee did the same thing. At 2.15 P. M., these two bees were still resting quietly, in the bright patch, on the lantern-side of the cage. On the window-side of the cage, one bee was clinging to the netting. No other bees were in sight.

EXPERIMENT 11.—*At 2.18 p. m., the light of the lantern was so adjusted as to illuminate all of the lantern-side of the cage and all of the side opposite. The floor was not illuminated by the beam.*

Five minutes later one bee was resting in the bright patch on the netting of the lantern-side of the cage. No other bees were in sight.

SERIES III (MAY 4, 1911)

EXPERIMENT 12.—*At 9.45 a. m., the cage ,which had been in a well lighted room, with a temperature of 78 degrees F., for several hours, was placed in a sunny window in such a position that the window-side of the cage, the side remote from the window, the top and a portion of the bottom of the cage were in the sunlight.*

At the beginning of this experiment, no bees were on any of the sides of the cage, one was roaming about the floor; no others were in sight. Mud cells containing bees were in the sunlight on the floor.

At 9.56 A. M., one male bee was in the sunshine on the window-side of the cage. No other bees were in sight. At 9.57 A. M., one female bee and two males were in the sunlight on the window-side of the cage. These bees would repeatedly fly against the netting on the window-side of the cage, and, when knocked backwards by the impact, repeat the act. At 9.59 A. M., seven bees, male and female, were either hovering before or resting upon the sunny netting on the window-side of the cage; two bees were resting in the sunlight on the floor. No other bees were in sight. At 10.00 A. M., eleven bees, male and female, were either hovering before or resting on the sunny netting on the window-side of the cage. No other bees were in sight.

EXPERIMENT 13.—*At 10.02 a. m., the cage was rotated, as gently as possible, through an angle of 90 degrees, thus placing the side upon which the bees were resting in the shade.*

At 10.04 A. M., six bees were in the sunlight on the window-side of the cage and one was sipping honey, in the sunlight, on the floor. No other bees were in sight. At 10.10 A. M., five bees were either resting on or hovering near the netting on the sunny window-side of the cage and four were in the sunlight on the floor. Three of the latter, two females and one male, were eating honey. Frequently a bee would fly in all directions about the cage and then finally alight on the netting on the sunny window-side of the cage.

Two bees were seen in copulo. (For description of the same see the section on "Mating Habits.")

The bees that had been feeding on the honey, on departing, made a short flight of orientation and then alighted on the sunny window-side of the cage. (For full description see the section on the "Feeding Habits.")

At 10.20 A. M., three were in the sunlight on the window-side of the cage, two were in the sunlight on the floor, and the rest were in the shadow.

From now until 11.14 *a. m., the cage was kept in a room well lighted by diffuse daylight but where it was impossible for the direct rays of the sun to reach the cage.*

At the close of the period two bees were noticed in copulo. No bees were in copulo at the time the cage was placed in the diffuse daylight.

EXPERIMENT 14.—*At* 11.30 *a. m., I placed an opaque screen over the upper six inches of the window-side of the cage. This caused the upper portion of the window-side of the cage, the side remote from the window, the top and a portion of the bottom to be in the sunlight.*

Two pairs of bees were noticed in copulo on the floor; one in the shadow and one with the anterior half of the body in the sunlight and the other half in the shadow.

At 11.35 A. M., several of the bees were flying at random about the cage. With few exceptions, whenever one attempted to alight it was on the sunny netting of that side of the cage through which the direct rays of the sun were entering. Sometimes the bee would strike the netting with such force that it would be knocked to the ground. At the same time that these bees were flying at random about the cage, other bees were wandering about on the floor, passing from sunlight to shadow and from shadow to sunlight, with no apparent system. On leaving the floor most of the bees flew, either directly or in a roundabout way, to the netting on that side of the cage through which the direct rays of the sun were entering. A few of the bees, on leaving the floor, climbed up the left side of the cage. (This side of the cage formed an angle of ninety degrees with the side upon which the majority of the bees alighted.) Of the few bees that climbed up the left side of the cage, some passed up through the sunlight and others through the shadow.

SERIES IV (MAY 5, 1911)

EXPERIMENT 16.—*At 10.00 a. m., the cage, which had been in diffuse daylight all morning, was placed in a sunny window in such a manner that the window-side of the cage, the top and, except for shadows cast by the framework of the cage, all other parts of the cage were in the direct sunlight.*

At 10.05 A. M., seven bees were resting on or hovering near the netting on the window-side of the cage and two were in the sunlight on the floor. No bees were resting on any other parts of the cage. Bees flew about the cage in all directions, frequently approaching the different sides of the cage, but never alighting on any except the window-side.

EXPERIMENT 17.—*At 10.08 a. m., the upper portion of the window-side of the cage was covered with an opaque screen six inches wide. This caused the upper part of the window-side of the cage to be in the shadow while the lower portion was in the direct sunlight. Except that the shadow on the floor was wider, the other parts of the cage were illuminated as in experiment sixteen.*

Immediately the bees left the shaded portion of the window-side of the cage. One ascended to the lighted top of the cage; while eight hovered near, rested upon or climbed up the sunny patch on the window-side of the cage. When a bee climbing upwards through the lighted portion of the side through which the direct rays of the sun were entering reached the lower border of the shaded portion of that side, it usually dropped backwards; sometimes only an inch or two, at other times to the floor, and repeated the performance over and over. Occasionally a bee would not stop when it reached the lower border of the shadow, but would continue on into the shadow a short distance and then either drop a few inches or fly to the lighted roof of the cage. On yet rarer occasions, a bee would, on reaching the lower border of the shadow, continue on into the shadow and rest there.

At 10.19 *a. m.*, a bee was noticed flying about the cage and hovering momentarily before each side. Presently it alighted, on the ceiling, near the side of the cage opposite the one through which the direct rays of the sun were entering. It then crawled along the ceiling, through the sunlight, to the shadow near the window-side of the cage and then dropped a short distance and repeated the hovering movements. That bee crossed the light in every possible direction; sometimes flying in the direction of the incoming rays, sometimes flying in the opposite direction, and sometimes crossing the rays at various angles.

EXPERIMENT 18.—*At* 11.20 *a. m., the room was darkened to about the brightness of twilight.*

In a short time all of the bees had retired to the bottom of the cage. The majority entered the mud cells.

EXPERIMENT 19.—*A beam from an electric projecting lantern was passed through the cage. On the lantern-side of the cage, the beam was eight inches wide and six and three-fourth inches high. On the opposite side the beam was eight by six and a half inches. A water cell was used as a heat filter. All other parts of the cage were in twilight brightness.*

This cage was watched continuously for fourteen minutes. During that time only one bee moved about the cage. That bee behaved as follows: Soon after the beam was projected through the cage, that bee climbed from the shadow into the bright patch on that side of the cage that was remote from the lantern. It continued its upward course until it had mounted the sunny wooden cross-piece at the top of that side; it then crawled down the netting for several inches and returned to the wooden cross-piece, along which it moved back and forth for a few seconds. It then moved along this piece, towards the right, until it reached a shadow. Returning to the light, it moved downward across the netting until it encountered the lower shadow, when it again crawled upward, across the netting, to the wooden piece at the top. After resting a few seconds, it moved leftwards a short distance and then turned and passed downward. On reaching the shadow, it reascended the netting, through the sunlight, to the top. Then, after moving towards the right for a short distance, it turned and crawled down the sunny netting until it reached the lower shadow; then, turning, it passed diagonally left upwards for a short distance and rested in the sunlight. At 11.38 A. M., the bee was basking in the sunlight, on the side of the cage remote from the lantern, and cleaning its body.

EXPERIMENT 20.—*At* 11.38 *a. m., the cage was rotated, as gently as possible, through an angle of* 180 *degrees. This placed the bee in the lighted patch on the lantern side of the cage.*

Immediately the bee moved upward across the netting, through the light and the shadow, to the wooden cross-piece at the top. Then, turning, it moved downwards. Just before reaching the lighted patch, it turned and moved upwards to the wood and then leftwards to the left wall of the cage and up that wall to where it joined the top of the cage. Along the edge of this wall the bee moved towards the side of the cage that was remote from the lantern. Except for a short distance at the beginning of her meanderings, all of these movements were made in the shadow.

EXPERIMENT 21.—*At* 11.39 *a. m., I held a mud cell, upon which a bee was resting, in the beam of light from the projecting lantern.*

For a few seconds the bee roamed about on the nest. Then it mounted my hand and moved about, at random, on it. All of these movements were performed in the bright light; but without any definite relation to the direction of the rays of light. Indeed, the bee crossed the rays in every possible direction.

EXPERIMENT 22.—*At* 11.43 *a. m., the heat filter was removed from the lantern so as to permit the heat as well as the light of the lantern to impinge upon the bee that was resting on my finger.*

The bee, which was a female, remained on my finger for eight minutes, and would have remained longer had I not dislodged her.

At 11.50 A. M., a bee climbed into the lighted patch on the lantern-side of the cage and remained there until the light was extinguished, five minutes later.

SERIES V (MAY 9, 1911)

EXPERIMENT 23.—*At 11.15 a. m., the cage was placed in a sunny window in such a position that the side next to the window and the top were strongly illuminated by the direct sunlight. The bottom and each of the other sides were partly in the sunlight and partly in the shadow.*

At this time the cage contained three females; all of the males and the remainder of the females had died. The bees flew about the cage in all directions; alighting sometimes on the sunny netting of the window-side of the cage and sometimes in the sunlight on the floor. Often they would remain on the floor several seconds. A bee alighted several times in the shadow above the lighted patch on the window-side of the cage.

At 11.28 A. M., two bees were resting, in the sunlight, on the netting of the window-side of the cage. The other bee crawled obliquely upwards to the wood above the netting of the window-side of the cage and then, after flying about in many directions, alighted in the shadow, on the left side of the cage.

At 11.40 A. M., a bee fed on honey and then, after a short flight of orientation, alighted on a mud cell and remained thereon, cleaning its mouth-parts and its head with its fore legs. A few moments later, another bee fed upon honey and flew into a mud cell, without making a flight of orientation.

At 11,46 A. M., two bees were in the mud cells and one was on the sunny netting of the window-side of the cage. The bee on the netting repeatedly climbed upwards, through the sunlight, to the lower edge of the shadow and then dropped backwards an inch or two.

At 11.48 A. M., two bees were on the window-netting and a third was sipping from a watch-glass situated in the shade. On leaving the honey and after making a short flight of orientation, the bee flew towards the left and alighted, in the sunshine, on that wall of the cage. After resting a few moments, it flew again to the honey. From the honey it returned to the sunny netting on the left side of the cage. After resting a moment, it flew again to the honey and from there to the sunny patch on the window-side of the cage. (This side of the cage formed an angle of ninety degrees with the left wall.) From this side of the cage the bee flew into a mud cell situated in the shade.

DISCUSSION OF THE EXPERIMENTS ON THE INFLUENCE OF LIGHT

The above experiments show conclusively that, when confined within a small cage and exposed to the direct rays of the sun, the bees of the species studied make certain flying movements that finally bring them in contact with that side of the cage through which the direct rays of the sun are entering. (Ex. 1, 2, 4—7, 9, 12—14, 16, 17.)

That this effect is produced, not by a bright patch, but by the direction of the rays of light is evidenced by the fact that a strong beam of light may be projected through the cage without arousing any responses from the bees upon which the direct rays of the light do not impinge. (Ex. 10, 11, 19, 20.)

It is also demonstrated that a shadow cast upon one of these parasitic bees while it is basking in the sun usually causes the bee to move. It may go to a light spot on the cage, or to the bottom of the cage, or to the mud cell that is its home. (Ex. 3, 8, 17, 18.)

Do these experiments justify the conclusion that these parasitic bees are positively phototropic? If by tropism we mean any differential response to a stimulus which results in the movement of that creature either to or from the source of the stimulus then these bees are undoubtedly positively phototropic or better positively phototactic; but if we limit the word tropism to that form of behavior in which an animal is mechanically forced by a stimulus to so adjust its body as to have each side equally stimulated, and then to move, in a straight line, either towards or away from the source of the stimulus, then the above statement needs qualifying. Before copulation, most males and females when exposed, while on the wing, to strong rays of light flew in paths sufficiently parallel to the rays to satisfy the most extreme form of the tropism theory; but, even then, some of the bees flew about the cage, in every possible direction before alighting upon the netting of that side of the cage through which the direct rays of the sun were entering (Ex. 13, 14), and, after feeding, for the first time, on honey placed either on bits of paper or in watch-glasses, a bee always made a short flight of orientation (Ex. 14). The males died soon after copulation and I could secure no reliable data of their behavior subsequent to mating. The females, however, lived several days after copulating, thus permitting a careful study of their behavior subsequent to mating. When alighting from flight such a bee would almost invariably alight on the netting of that side of the cage through which the direct rays of the sun were entering; but, in her flight, she would frequently cross the rays of light in every possible direction (Ex. 23). In roaming about on foot, the bee would cross the rays of light in every possible direction (Ex. 21). Frequently the bee would remain exposed to the direct rays of the sun without making any outward response (Ex. 22). Under the same external conditions, the same bee, at successive moments, did not always make the same response to the impinging light (Ex. 20, 23). Occasionally a bee would fly about the cage, crossing the rays of light at every possible angle, and hover before each side of the cage as though examining it (Ex. 17). These striking variations from a fixed response militate against calling this behavior a tropism in the restricted sense mentioned above.

It seems more in harmony with the facts to assume that light, heat, hunger, sexual restlessness and, perhaps, other factors arouse in these bees an impulse to roam from home, and that, coupled with this impulse to roam, there is an instinctive tendency to seek freedom in the direction of the incoming rays of light. When following this instinctive tendency fails to bring freedom, the bee tries other methods. In this endeavor, many bees make haphazard flights in all possible directions, usually concluding by yielding to the instinctive impulse to move in the direction of the rays of light and towards their source; while yet other individuals, in a more systematic manner, repeatedly hover before each side of the enclosure as though looking for an opening. When, in their ramblings, they find something which it is to their interest to revisit they make a flight of orientation which furnishes them with memory pictures that assist them in revisiting the place. At twilight these bees are stimulated to seek the mud cells that serve as home. When we state that these parasitic bees are endowed with a pronounced tendency to move in the direction of the rays of light and towards their source; but that they do not invariably so react, for they frequently display unpredictable variations, we have given as strong a mechanical interpretation as the facts warrant. If it is desirable to call this kind of a response a tropism then these bees are positively phototactic.

It seems to me that there is a difference between the behavior just described and tropism in the strictest sense. In the narrow sense mentioned a tropic response would be similar to the turning of a magnetic needle towards the pole and would be subject to like perturbations. It seems to me that the responses of these bees towards light are more like those of a small boy towards the strains of an invisible brass band that has suddenly begun to play. In the majority of cases the boy will make movements that will take him in the direction of the source of sound; but he is not mechanically compelled to invariably make such movements. Finding his way barred the boy may seek an indirect path of exit. If intensely interested in a saucer of cream or other occupation, his movements may bear no relation whatsoever to the sound stimulus. Occasionally a child may make no response to the sound, although an onlooker can see no reason for its passivity. The behavior of these parasitic bees is quite parallel. When exposed to the direct rays of the sun or other strong light, such a bee will usually fly in the direction of the rays of light and towards their source. Failing to reach freedom by that method, it may seek to escape by making movements that bear no constant relation to the direction of the rays of light. Intent on feeding or mating, it may make numerous complex movements that bear no relation whatsoever to the light stimulus. It may even remain outwardly inactive in the presence of a strong light without the onlooker being able to discern any reason for its passivity. I am anxious not to be misunderstood. I do not consider these cases to be identical; but they are similar. Without predicating either curiosity or logical thinking to these parasitic bees and admitting that the behavior of the boy is more flexible, it does seem that the parallel between the light stimulated bee and the band-excited boy is too marked for the two cases to be considered different in kind.

Bohn puts much stress upon what he calls "differential sensibility" ("sensibilité differentiellé"), which is the tendency of many animals to rotate through an angle of 180 degrees when confronted with a sudden change in the mechanical or physical condition of the environment. These bees in their movements did certain things that reminded me of this factor. When a bee that was climbing up a sunlit wall came in contact with the lower edge of the shadow it usually dropped backwards into the light (Ex. 4, 9, 17). There was no revolution of the body through 180 degrees, yet this marked reversion in behavior induced by contact with the shadow might well be considered an example of "differential sensibility"; but, this dropping backward was not an invariable movement. Sometimes the bee continued on into the shadow before dropping; at other times it not only continued into the shadow, but it rested there for some time; at yet other times it continued on into the shadow without dropping at all. But this dropping reaction does not prove that the movements of these bees are tropisms in the narrow sense mentioned above. If the bee were seeking to escape in the direction of the rays of light, on reaching the shadow, the most natural response would be a return to the light.

CONCLUSIONS

1. These parasitic bees used the mud cells out of which they were hatched as homes, retiring to them at night.

2. On leaving a quantity of honey from which it was feeding for the first time, the bee always made a short flight of orientation. This indicates that they possess memory.

3. Both males and females fed on the honey.

4. The bees were so tame that, without any preliminary training, they would rest on one's finger and eat honey therefrom.

5. These bees mated in either the sunlight or shade; but always on a vertical or horizontal support, never on the wing.

6. These bees are endowed with a pronounced tendency to move in the direction of the rays of light and towards their source; but do not invariably so react, frequently they make unpredictable responses.

7. Light, heat, hunger, sexual restlessness and, perhaps, other factors arouse in these bees an impulse to roam from home. Coupled with this impulse to roam, there is an instinctive tendency to seek freedom in the direction of the rays of light. When following this instinctive tendency fails to bring freedom, the bee tries other methods. In this endeavor many bees make haphazard flights in all possible directions; while others, in a more systematic manner, hover repeatedly before

the sides of the enclosure. If such behavior can be called a tropism then these bees are positively phototactic.

8. Without predicating curiosity or logical thinking to these bees and granting that the behavior of the boy is more flexible, it seems to the present writer that the reaction of these bees towards light resembles more the response of a small boy to the music of a brass band than it does the turning of a magnetic needle towards the pole.